report of indian productivity team

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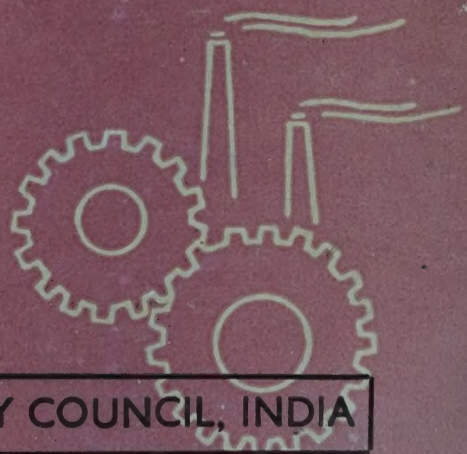
Quality Control in Japan, USA and Britain



NATIONAL PRODUCTIVITY COUNCIL, INDIA

NATIONAL PRODUCTIVITY COUNCIL

NPC activities are directed towards the objective of increasing the national wealth and the standard of living of the people by stimulating increase of productivity in various spheres of the nation's economy, particularly in industries.

The National Productivity Council is an autonomous organisation established by the Government of India. It has on it, representatives of the Government of India, organisations of employers, workers and various other elements interested in the productivity drive. Established in 1958, the Council conducts its activities in collaboration with other organisations and institutions in industrial productivity. It is carrying the productivity drive to the plants through the Local Productivity Councils which have been established in industrial centres all over the country.

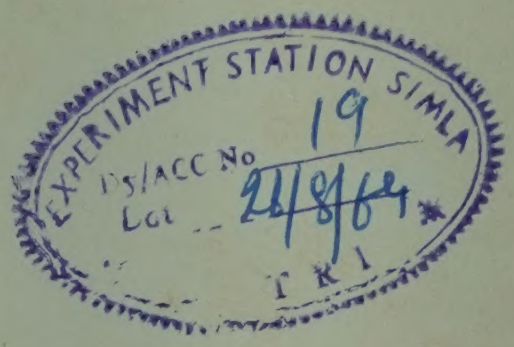
The purpose of NPC is to stimulate productivity consciousness in the country; to maximise the utilisation of all available resources; to wage war against waste; to help secure for the people a better and higher standard of living. To this end, it collects and disseminates information about techniques and procedures of productivity and organises a number of programmes. It arranges and conducts seminars, conferences, study groups, lectures and training courses: maintains and provides Advisory Service and Technical Enquiry Service, utilises the media of publications, films and exhibitions for propagating the concept of productivity. Through these media it seeks to carry the message of productivity.

NPC stimulates technical exchange within the country by organising in-plant visits and in-country productivity teams: it lays the greatest emphasis on programmes of training in various subjects of productivity to suit different levels of management and technicians. It aims at developing appropriate attitudes of workers towards productivity.

NPC sponsors training abroad in industrial engineering, industrial management and industrial relations. It is also sponsoring productivity teams abroad for studies in general subjects of productivity and in specific subjects of individual industries.

Reports of these Teams are published by NPC. This is the twenty-sixth Report in the series. NPC is publishing these reports so that industrial managements in India may gain the necessary knowledge for maximising productivity within their concerns.

npc report number 26



Quality Control in Japan, USA and Britain

June 1963

NATIONAL PRODUCTIVITY COUNCIL
38, GOLF LINKS
NEW DELHI, INDIA

The National Productivity Council records its deep appreciation and gratitude for the efforts made by the United States Agency for International Development Mission to India in sponsoring and assisting this Productivity Team

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PREFACE

We, the members of the Productivity Team on Quality Control in Industry, have pleasure in submitting this Report on the application of quality control techniques in the industries in Japan, the USA and the UK.

We have attempted to present our observations in as objective a manner as practicable. We are of the opinion that we have in our country enough competent persons to implement successfully quality control programme provided an opportunity is given to them. With this end in view, we are directing our Report to the top management of the Indian industries and hope that they will find a clear exposition of the quality control practices—concepts, techniques, organisation, personnel, benefits, evaluation, training etc.—abroad which will stimulate them to implement these in their own organisations.

We have also presented a detailed exposition of some of the techniques, case studies, developments in the field of inspection and metrology, which will be of interest to technicians and quality control personnel.

We feel that the promotional activities in the field of quality control always play an important role in spreading and understanding the quality control philosophy. We have presented informations regarding this aspect in detail so that the Report should be of interest to persons and organisations engaged in promotional activities.

The opinions expressed in this Report are unanimous.

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1 : Introduction

THE need for improving the quality of the goods of Indian industries is increasingly felt: the consumers' requirement of better quality products, the scope for exporting products of Indian industries, together with expanding markets both within and outside the country, have focussed attention on improving the quality and increased productivity. This challenge can only be met if an industry produces goods of improved quality at lower costs. Quality control techniques play an important role in improving and maintaining the quality at lower costs with the available resources. With the maintenance of standard quality, great economy will be achieved in production and in distribution.

It was felt that the visit of an Indian Quality Control Team to countries which have longer experience in the field, would be of great value to Indian industries at this stage.

Recognising this need the National Productivity Council of India sponsored a Team on Quality Control with the financial assistance from the United States Agency for International Development.

Terms of Reference

The broad outlines of the terms of reference of the Team were:

i. Management Concept, Organisation and Evaluation of Quality Control;
ii. Tools and Techniques;
iii. Inspection in Industry;
iv. Quality Control and Standardisation; and
v. Training, and Promotional Activities.

Prior to departure abroad, the Team members undertook an in-country tour visiting industries and organisations connected with Quality Control in Calcutta, Bombay, Madras and Bangalore. A list of industries and organizations visited by the Team is given in Appendix A.

The Team during their tour abroad visited industries, organisations and institutions in Japan, USA and UK. A list of the places visited is given in Appendix B.

Acknowledgement

The Quality Control Team expresses its appreciation and gratitude to:

(1) The NPC of India for giving them an opportunity to study a subject of such vital importance to the country and at the most appropriate time when the industry is fast expanding;

(2) The United States Agency for International Development Mission to India, the US-AID Mission to Japan, the Japanese Productivity Centre and the British Council for their kind guidance and help;

(3) The Project Managers in Japan, USA and UK for the excellent arrangements made in connection with the Team's visit to various industries and organisations; and

(4) The industries and organisations at home and overseas for the kind courtesy extended and making best possible arrangements for discussions during the Team's visit.

2 : Development of Quality Control

Historical Review*

QUALITY control is as old as industry itself. From the time man began to manufacture, there has been an interest in quality of output. As far back as the Middle Ages the medieval guilds insisted on a long period of training for apprentices and required that those seeking to become master-craftsmen offer evidence of their ability. Such rules were, in part, aimed at the maintenance of quality. In more modern times, factory inspection and research, pure food and drug acts, activities of professional societies—all have sought for years to assure the quality of output. Quality control has thus had a long history.

On the other hand, statistical quality control is new. The science of statistics itself goes back to only two to three centuries, and its greatest development has been in the last sixty years. Early applications were made in astronomy and physics and in the biological and social sciences, but it was not until 1920's that a statistical theory began to be applied effectively to quality control. A factor in the birth of statistical quality control in the 20's was the development in immediately preceding years of an exact theory of sampling.

In USA

The first to apply the new statistical methods to the problem of quality control was Dr. Walter A. Shewhart of the Bell Telephone Laboratories. In a memorandum prepared on May 16, 1924, Dr. Shewhart made the first sketch of a modern "control chart". The new technique was subsequently developed in various memoranda and articles, and in 1931, Dr. Shewhart published a book on statistical quality control, entitled "Economic Control of Quality of Manufactured Product". This book set the pattern for subsequent applications of statistical methods to process control. Two other Bell system men, H. F. Dodge and H. G. Romig, took the leadership in developing the application of statistical theory to sampling inspection, the culmination of their work being the new well-known Dodge-Romig Sampling Inspection Tables. The work of Shewhart, Dodge and Romig constitutes much of what today comprises the theory of statistical quality control.

In the early 30's, these Bell system men, in collaboration with the American Society for Testing Materials, the American Standards Association and the American Society for Mechanical Engineers, undertook to popularize the new statistical methods in the United States. Dr. Shewhart also visited London where he met prominent British statisticians and engineers.

In the United States, despite the publicity given to the new methods, the rate of adoption was at first slow. Prof. H. A. Freeman, who was promoting statistical quality control at Massachusetts Institute of Technology, ascribed this sluggish response of the early years to (1) "a deep-seated conviction of American production engineers that their principal function is to so improve technical methods that no important quality variations remain, and that in any case, the laws of chance have no proper place among 'scientific' production methods", and (2) "the difficulty of obtaining industrial statisticians who are adequately trained in this fairly complicated field." In 1937 probably not more than a dozen single enter-

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* The historical review reproduced from Quality Control and Industrial Statistics, A.J. Duncan, Richard D. Irwin Inc., Illinois, USA.

For development of Quality Control in individual firms, see Appendix H.

prises in American mass-production industries had introduced the new technique into their ordinary operations.

This initial coolness of American industry towards statistical quality control was rapidly overcome during World War II. The outbreak of the conflict in 1939 set the United States to thinking of national defence. This meant enlargement of military personnel and material. The armed services began to enter the market as large consumers of American output and, as such, had an increasing influence on quality standards.

The influence of the military on the adoption of statistical quality control was of two kinds. First, the armed services themselves adopted scientifically designed sampling inspection procedures. This put an indirect pressure on the suppliers of military material to adopt quality control procedures that would lower the rejection of their output by the service procurement officers. A leader in the use of statistical techniques in the armed forces was Gen. Leslie E. Simon whose book, "An Engineers' Manual of Statistical Methods" appeared in 1941. Gen. Simon was then a major in the Ordnance Department of the United States Army and Assistant Director of the Ballistic Research Laboratory at Aberdeen, Maryland. He had begun his work in quality control at the Picatinney Arsenal as early as 1934.

Educational Programme

The second step taken by the military was an educational programme. At the request of the War Department, the American Standards Association initiated in December 1940, a project that eventuated in the American War Standards Z1.1—1941 and Z1.2—1941, "Guide for Quality Control and Control Chart Method of Analyzing Data", and American War Standard Z1.3—1942, "Control Chart Method of Controlling Quality during Production". These gave concise statements of American control-chart practice. In July, 1942, an intensive ten-day course in statistical quality control was given at Stanford University to representatives of war industries and procurement agencies of the armed services. Later, the course was shortened to eight days and given at Los Angeles. These courses were made possible by the financial backing of the Engineering, Science and Management War Training Programme of the United States Office of Education. The success of this early educational programme led the Office of Production Research and Development of the War Production Board to establish similar courses throughout the country. Accordingly, from 1943 to 1945, 810 organizations from 35 different states sent representatives to attend one or more of the 33 intensive courses on statistical quality control that were offered by the OPRD. Among these 810 organizations were 43 different educational institutions, most of whose representatives were faculty members who attended to prepare themselves to give instructions in quality control.

Mention should be made at this point of the war-time research in statistical quality control and especially of the Statistical Research Group, Columbia University, Applied Mathematics Panel, Office of Scientific Research and Development. This Research Group was organized in July, 1942, by Harold Hotelling under the auspices of Warren Weaver, Chief of the Applied Mathematics Panel. It continued in existence until September, 1945. Members of the staff were drawn from universities and research organizations throughout the country. It advised and assisted the Army, the Navy, and the Office of Scientific Research and Development on statistical aspects of problems arising in their activities. It investigated certain problems of a predominantly statistical or probabilistic character and developed, reveiwed and expounded statistical techniques. Included in its contributions to statistical quality control was the preparation of the Navy manual on sampling inspection by attributes, which was later expanded and its underlying principles explained in "Sampling Inspection", published by McGraw-Hill Book Company (1948). Another contribution to industrial statistics was its volume on "Selected Techniques of Statistical Analysis for Scientific and Industrial Research and Production and Management Engineering", published by McGraw-Hill (1947). One of the most important contributions to statistical quality control was the development by Dr. A. Wald of sequential sampling. Indeed, so important was sequential analysis deemed by the United States Government that it withheld publication of Dr. Wald's original paper until June, 1945.

The training courses and research programmes sponsored by the Federal Government

produced in various industrial centres nuclei of interested and trained personnel. Subsequent to the completion of introductory courses, quality control societies were formed in various localities, the meetings of which offered continuing opportunities for the exchange of ideas and the education of new members. In Buffalo, the Society of Quality Control Engineers in co-operation with the University of Buffalo began in July, 1944, the publication of "Industrial Quality Control" under the editorship of Dr. Martin Brumbaugh. The new publication quickly attained a national circulation. All of this led to growing use of statistical quality control in the later years of the war. Shortly after the war, sufficient interest developed to form a national organization known as the American Society for Quality Control. George D. Edwards, Director of Quality Assurance of the Bell Telephone Laboratories, was the first president of the new organization, and Dr. Walter A. Shewhart was made its first honorary member. The American Society for Quality Control was born in February 16, 1946. In 1957 it had 96 local sections in the United States, Canada and Mexico, with a membership in excess of 10,000. The new national organization took over the publication of INDUSTRIAL QUALITY CONTROL and became the leading force in promoting the use of statistical quality control in the North American continent. There is also a section in Japan.

In Britain*

In Britain Statistical Quality Control made more rapid progress in the early years than in the United States. Following Dr. Shewhart's visit to London in May, 1932, Dr. Egon S. Pearson read a paper before the Royal Statistical Society on the industrial application of statistics. Shortly afterward the Statistical Society set up an Industrial and Agricultural Research Section and authorized a supplement to the regular journal for publication of papers pertaining to this new field of application. It is interesting to note that the provisional committee to arrange for this new section had representatives from Imperial Chemical Industries, the London School of Hygiene, the Boot Trade Research Association, the Department of Applied Statistics, University College, London and the School of Agriculture, Cambridge; and at its first meeting the opening paper was read by Dr. R. H. Pickard, Director of the British Cotton Industry Research Association. The British Standards Association showed its interest in these newer methods by putting out a text prepared by Dr. E. S. Pearson entitled "The Application of Statistical Methods to Industrial Standardization and Quality Control". In addition, G.E.C. Research Laboratories published a handbook entitled 'Quality Control Chart Technique when Manufacturing to Specification', which is now published as BS2564 (1955) by the British Standards Institution. During this period, pioneers in the application of statistical techniques in industry were Dr. B. P. Dudding of the General Electric Company and L. H. C. Tippett of the British Cotton Industry Research Association.

Early in the summer of 1943 the Ministry of Production issued, through the medium of its Regional Organisation, a leaflet on Quality Control which aimed at stimulating the interest of manufacturers in, what is undoubtedly proving to be one of the greatest of recent advances in production technique. As a result, the Birmingham District Production Committee of the Ministry set up a Quality Control Panel which was conspicuously successful in its educational and advisory work among engineering and other firms in the Midland Region.**

The response of British industry to the new statistical methods was quick and widespread. By 1937 they were being applied to such products as coal, coke, cotton yarns, cotton textiles woollen textiles, spectacles glass, lamps, building materials and manufactured chemicals. Application was further stimulated by the war, and in 1945 the Royal Statistical Society divided the original Industrial and Agricultural Research Section into two sections—a Research Section and an Industrial Applications Section. The latter has formed "local groups" in London, Birmingham and six other areas. These are similar in some respects to the local sections of the American Society for Quality Control. In 1952 the Royal Statistical Society began publication of the journal "Applied Statistics".

The British Productivity Council has been doing promotional work in the field of Quality

* Based on A.J. Duncan, Op. Cit.

** *Quality Control in Production*, H. Rissik, Sir Isaac Pitman and Sons Ltd., London.

Control. They organise seminars and conduct short courses in the field of quality control. Two booklets, one on Quality Control and the other on Case Studies in Quality Control have been published by the Council.

The Institution of Production Engineers has taken keen interest in popularisation of quality control at the top management level. The institution has prepared and circulated material on quality control for the attention of Directors and Managers of British Industry.

To promote the quality control activities further the National Council for Quality and Reliability is being set up. The importance attached to quality control in British industry can be gauged by the leading article in *Time and Motion Study* (October 1961): "More than three-quarters of the manufacturers in Britain employ fewer than 100 people each. The task of convincing them that it is possible to instal modern methods to control the quality of their products is a formidable one. Their collective output is already substantial, but they tend to remember only their individual share of it. If they can be persuaded by ensuring that the product is properly made from the start, the existing labour force and plant can enlarge the current output considerably, Britain's export position can alter dramatically."

In Japan *

Modern Quality Control or Statistical Quality Control was first initiated in Japan by Y. Ishida at Tokyo Denki Co. (the present Tokyo Shibaura Electric Co.) in the manufacture of incandescent lamps. This was done earlier to the commencement of World War II. Some important developments prior to 1945, were the translation of E.S. Pearson's "Mass Production Control and Statistical Method" by Dr. T. Kitagawa and Y. Ishida; initial Statistical Quality Control application in the Army Administration Headquarters; and studies of sampling inspection under the guidance of Dr. Z. Yamauti.

The period 1946-1950 may be called as the introduction period. Just after the World War II, Statistical Quality Control was introduced by the US Army in Japan. Around 1948, quality control in the electric communication industry was started by the introduction of Shewhart Control Charts. Also research in statistical quality control was started by a group of professors of Engineering and Mathematics from several universities and by engineers from private firms, and since 1948 at the Union of Japanese Scientists and Engineers (JUSE). In September 1949, lecture courses in Statistical Quality Control were started for managers and engineers. Those who participated in these early programmes were from chemical and steel industries. But now all types of industries send their engineers. In March 1950 the first issue of the monthly journal STATISTICAL QUALITY CONTROL came out.

In July 1949, the industrial standardisation law was enforced by the Ministry of International Trade and Industry. It was decided to stamp the 'JIS' mark on commercial goods by authorisation of the Minister of International Trade and Industry. The application of quality control techniques and procedures in industry was a prerequisite for obtaining the 'JIS' mark. This legislation promoted the application of quality control methods in industry. During this period Japanese Standards Association (JSA) held many research meetings on quality control. As a result of this Japanese Industrial Standards for Control Chart and Sampling Inspections have been published. JSA publishes a periodical on standardisation.

In July 1950, Dr. W. E. Deming from USA gave lecture courses for eight days. This was organised by the JUSE.

Generally speaking Quality Control during 1946-1950 was inclined towards mathematical statistics. Quality Control committees were organised in more progressive firms.

The period 1951-1954 may be called as the development period. The promotional activities during the introduction period and later resulted in a "Quality Control boom" in the Japanese industries. A number of lecture course meetings were held at various cities under sponsorship of various organisations and the number of participants were about 18,000 for a period of 4 years. Also various lecture meetings were held within companies. The

* Based on the material on QC in Japan, QC Specialists Study Team, January 1958. This Team visited USA to study QC methods.

publication of technical books on Quality Control flourished. It is said that by this time, there was no one who did not know the term 'Quality Control' among first class engineering firms. Many firms reported improvement in quality, increase in production and reduction in cost as a result of quality control programme. The number of professional organisations and enterprises having quality control committees increased.

In 1951, the Deming Prize was established to promote further Quality Control in Japan, from the funds of the 8-day course of Dr. Deming. The prize is divided into Deming Prize proper and Deming Performance Prize. The Deming Prize proper is given to persons who have significantly contributed to the theoretical development, application and education in the field of Statistical Quality Control. The Deming Performance Prize is given to companies who have demonstrated the successful applications of quality control programme, under the leadership of the president of the company.

The Ministry of International Trade and Industry introduced in 1953 a scheme of honouring the factories for outstanding performances in the field of standardisation and quality control; such a factory would be given the Minister's (of International Trade and Industry) prize.

In 1954, the Quality Control Literature Prize was established to honour the individual authors who have made worthwhile contribution in the field of quality control.

During this development period of quality control, statistical methods caught the imagination of the engineers (and in fact such a knowledge is considered amongst the Japanese engineers as a 'must') and distinct technical improvements were achieved by using these methods in the analysis of processes and locating the sources of variation. At present statistical methods are very popular amongst Japanese engineers and probably Japan has the highest percentage of engineers with a knowledge of statistical methods.

The Japanese Union of Scientists and Engineers (JUSE) in 1954 invited Dr. J. M. Juran from the USA to give lectures for top management personnel and departmental heads of various industries. These lectures emphasised that Quality Control should be thought of as an integral part of management control and that it was the responsibility of the top management to introduce it as such. JUSE in 1951 initiated research on physical sampling of materials, a topic directly related to Quality Control.

Quality Control has now become, particularly after 1955, an integral part of management control. Top management have been evincing keen interest in Quality Control activities. The Ministry of Defence has started applying acceptance sampling procedures (MIL-Q-5923C) to all factories producing items for defence department. This has also stimulated the application of quality control.

The development of Quality Control in Japan has been aptly summarised by J. M. Juran*: "Attention to quality has become virtually a national movement. With the surrender in 1945 there was swift realisation that Japan must rebuild an industrial economy or be doomed to a continuing marginal level of existence; that for a large population on a small island territory this economy must be based on extensive export and import; that export and import must now be done by trade, not by conquest; and that to trade one must have quality products. The industrial companies, their associations, their technical societies and their government—all attacked this problem. They supplemented their knowledge by import. The American imports included Deming on Statistical Quality Control and this department (Juran) on Management of Quality Control. They created independent inspection laboratories to certify goods for export.

"An intense competitive stimulus was born a decade ago with the creation of the Deming prize. This prize, awarded by a committee of the JUSE, has become a recognised symbol of excellence in quality. The companies who receive it (there have been about two dozen in a decade) have earned for themselves an accolade reminiscent of the early days of the Army-Navy E. Here again, it must be seen to be believed. Considering the use of the pictures of the Deming prize in product advertising literature, on television, on billboards, etc., it may well be that the benign visage of Dr. Deming has been viewed more often by the Japanese population

* Japan Revisited, Management's Corner, *Industrial Quality Control*, March 1961.

then even that of General of the Army, MacArthur. The image is turned inward as well. When Nippon Motor Company received the prize, a miniature copy of the medal was struck and given to each of the 7000 employees. When Management's Corner participated in the award ceremony for Kurake Spinning Co., we were in the middle of an event as memorable as the launching of a giant naval vessel.

"Nor are the Japanese content to rely indefinitely on the foregoing. This department (Juran) found itself participating in the first National Quality Month in Japan. An imposing array of Industrial, Professional and Governmental bodies were collaborating in a massive public relations movement. A special Quality flag was flying everywhere. Special conferences on Quality Control were being conducted in 13 principal cities. Consumer reaction to quality was solicited within Japan, by the press, by the broadcaster, by advertising. Japanese quality performance was propagandised abroad..... It is truly an outstanding achievement. To the outside observer it demonstrates what men of energy can do when they recognise a major problem and mobilize their resources to solve it."

In India*

In India the earliest attempt to introduce the idea was by Professor P. C. Mahalanobis about 1935, when he tried to obtain support from Government and scientific organisations in this connection. It was only in 1944, however, that the first practical steps were taken with the establishment of a Committee of Statistics, Standards and Quality Control by the Council of Scientific and Industrial Research. The first training course in Statistical Quality Control was given in the Indian Statistical Institute, Calcutta in 1945-46. A visit to India in 1947-48 by Dr. Walter A. Shewhart, the originator of the Statistical Quality Control technique, created widespread interest in the subject and Statistical Quality Control method came to be gradually adopted at some of the industrial centres of India. Another result of Dr. Shewhart's visit was the formation of an Indian Society for Quality Control in Calcutta. Subsequently other associations were started, as for instance the Board of Management for Quality Control, Bombay, and the Quality Control Association, Bangalore. The Indian Standards Institution set up a Committee on Quality Control and Industrial Statistics in 1948. A little later the Ahmedabad Textile Industries Research Association developed a centre of Statistical Quality Control at Ahmedabad, which has been actively assisting the member mills in introducing the Statistical Quality Control techniques.

Progress, however, was slow mainly because of the lack of Statistical Quality Control personnel with adequate training. At the invitation of the Government of India, the United Nations Technical Assistance Administration sent an expert team to India in 1951-52 to organise training courses in Delhi, Calcutta, Madras and Bombay and 153 persons, deputed by Government departments and industrial concerns, received training at these centres. In 1953, the Indian Statistical Institute established a whole time Statistical Quality Control Unit with a staff of three under a grant from Government of India. In March 1954, the Statistical Quality Control Policy Advisory Committee was established with Shri Chintaman D. Deshmukh, the then Finance Minister, as Chairman. As decided upon by the Policy Advisory Committee, three Statistical Quality Control Units were initially started under the administrative control of the Indian Statistical Institute, in Bombay, Bangalore and Calcutta. Now there are Units in Baroda, Coimbatore, Delhi, Ernakulam and Madras. They provide technical assistance to member enterprises, give training in Statistical Quality Control and generally promote the use of Statistical Quality Control in Indian Industry.

At the invitation of the Indian Statistical Institute, W. A. Shewhart came to India again at the end of October 1954, for a stay of three months. The services of two Japanese experts, Mr. G. Taguchi and Mr. T. Hanada had already been secured by the Institute. Mr. D. J. Desmond, a well-known Statistical Quality Control Consultant of UK, came to India under the Colombo Plan in December, 1954.

Second Conference

A conference was held under the auspices of the Indian Statistical Institute in Calcutta in the third week of January, 1955. It was the second of its kind, the first being the one in January,

* Based on a report by the Indian Statistical Institute, Calcutta.

1948, also at Calcutta. In both these conferences the promotion of Statistical Quality Control was discussed at considerable length. But the object of the 1955 conference was not so much to promote the use of Statistical Quality Control methods as to bring together persons engaged in Statistical Quality Control work and to pool their experience for formulating a programme of action for the future. This conference was to stress the technical aspects of Statistical Quality Control like installation, maintenance, suitable techniques for different industries and for proper methods of imparting instructions in the use of Statistical Quality Control methods. The conference was, therefore, restricted only to such persons who had knowledge or experience of Statistical Quality Control work and could participate in the technical discussions or who could explain the views of industry and management in relation to questions of policy.

Since 1955 the Statistical Quality Control movement has been strengthened by the active interest and participation in the movement by many more organisations. Chief among them are: South India Textile Research Association, Bombay Textile Research Association, National Productivity Council, Silk Research Association, Indian Institute of Technology, Kharagpur, Indian Institute of Science, Bangalore, and many universities.

Another conference on Statistical Quality Control was held in Calcutta during December 1958 under the joint auspices of the National Productivity Council and the Indian Statistical Institute, Calcutta. More than 50 technical papers from various types of industries were presented in several sessions of the conference.

Foreign specialists, who have visited India since 1955 in connection with Statistical Quality Control work at the invitation of Indian Statistical Institute, include Prof. Barnard from UK, Mr. A. D. Raich, Dr. E. R. Ott, Dr. W. R. Pubst Jr., Dr. L. A. Knowler from USA.

One of the foreign Statistical Quality Control specialists, who visited India recently, says that Indian industry today is in some respects at about the place that American and Japanese industry were a decade ago when methods were first introduced. The statistical tools of quality control did not fulfil expectations until management and engineers learnt how to apply them economically in their own establishments. As American and Japanese managements found these new methods an excellent paying proposition, Statistical Quality Control virtually swept through whole industries and became part of the basic industrial framework of these countries. Scientific societies also helped to spread Statistical Quality Control movement in the USA and Japan. Progressive managements in India are showing interest in effective use of the methods. With the training of competent staff and spurred by the drive for technical advancement, it can be expected that these methods will sweep through Indian industry within the next few years.

In all the three countries, during the last few years quality control concept has developed towards total quality control as detailed in Appendix C. This has been found to be readily acceptable to the industry.

3 : Management Aspects of Quality Control

A REMARKABLE feature of the industries visited in Japan, USA and UK was the seriousness with which the top management had come to regard Quality Control as an overall management function. As a result of deep interest on the part of top management, a well organised Quality Control programme was noted in most of the industries visited abroad. Though these varied in details as to functions, techniques employed, evaluation procedures and responsibilities of staff, the ultimate object of the Quality Control programme was directed towards the product quality and consumer satisfaction. To this end 'quality' objectives were set, management policy was enunciated, organisation structure was developed, evaluation procedures were defined and qualified personnel were entrusted with the responsibility of achieving the management's 'quality' objectives. These aspects will be discussed with regard to some of the industries in Japan, USA and UK in later sections.

Management was constantly endeavouring to improve their product quality and reduce costs. In most of the factories visited a research department existed. Also the management was evaluating quality level of products of the competitors both at home and abroad. Any new discovery or change that might be developed in their research department and found worthwhile, would be introduced into production process at the earliest. For instance, in Eastman Kodak Co., USA, a new product modification is put in production, on an average, once in seven days. In Radio Corporation of America, USA, the first transistor was produced within a short period after the announcement by the Bell Telephone Laboratories. It is this alertness and interest for better products that has made managements take up seriously to Quality Control.

Another impressive feature noted was, managements' desire to see that no defective product leaves the factory. For this purpose, in addition to the final inspection, there were overchecks on the finished products. Quality control departments, in most of the factories visited in USA could withhold from delivery the finished product which was not considered satisfactory for customer's use. In case of shipment of non-standard products, special committees had to sanction such delivery and invariably the customer's permission was sought for such delivery.

Concept and Policy

Management concept and policy regarding quality control in several factories visited in Japan, USA and UK are discussed in the following sections. The discussions the Team had with managements and the literature supplied by the factories to the Team give a clear idea of management's thinking on Quality Control.

JAPAN

The fundamental policy on Quality Control at Tokyo Shibaura Electric Co. Ltd. (Toshiba), Japan, is reproduced below:

Control of quality is one of the important control functions of management. Those responsible for control shall always grasp quantitatively, within their range of assignment, the quality of the products as well as their production volume and production cost, and strive to maintain and improve the level of quality.

The following policy statement is issued for this purpose;

(a) Quality shall be determined according to the fundamental policy of the company by considering both value and price of the product. Therefore, the chief executive of the division shall be held responsible for determining the level of quality, and its adequacy shall be studied continually.

(b) The control of quality is the method of coordinating sales, production, inspection, engineering, research and all other efforts necessary to maintain and improve quality, and to make them most effective.

(c) In production, quality shall be controlled by taking up the more important characteristics, studying and analysing past production performance records, and establishing control limits. Statistical methods of quality control shall be utilised to the fullest extent.

(d) Quality-mindedness of everyone having to do with production shall be called upon and the responsibility for quality shall be made clear for each duty.

(e) In quality control the determined quality level shall be maintained, and furthermore continuous effort in research and improvement shall be made to be always a step ahead for quality control to be effective.

(f) Each person in charge shall report clearly and rapidly to his superior the results of investigating quality related to his duties.

Each division has determined its policy according to the above statement and is conducting quality control based on it. Thus, if we take a look at only certain parts of our company, there might seem to be no relationship among each other, but there actually is this basic policy running through them.

UNITED STATES

In Eastman Kodak Co., USA, the Quality Control organisation asks three questions:

(a) Will the product, made to specifications, do the job for which it is intended in a manner which will not injure the name of Kodak?

(b) Is the product going out of the door, up to specifications?

(c) Are purchased parts and materials satisfactory and manufacturing processes under control, so that costs due to waste are at a minimum?

In Bausch and Lomb Inc., USA, the motto was "good or better products" and customer satisfaction was their main objective. According to the management, for fuller customer satisfaction the following sequence had to be followed:

	Responsibility
(a) What characteristic will satisfy customer?	Marketing
(b) These characteristics are spelled out in an unambiguous way.	Engineering
(c) Materials of required quality should be purchased.	Purchasing
(d) Manufacturing	Manufacture
(e) Inspection	Inspection
(f) Shipping	Production Control

The management of Bristol Myers Co., USA, states: "When a company makes and sells a product, certain standards must be met for that product to be acceptable legally and competitively. Management establishes these general standards, and adherence to them is the joint responsibility of Production and Quality Control. In order to produce acceptable merchandise, the proper degree of quality must be built into it by production. The measurement of quality is a function of Quality Control. If we start out with sub-standard raw materials, obviously it becomes impossible for production to fulfil its responsibility. The scope of Quality Control must extend, therefore, even into the realm of the supplier, in order to assure production of acceptable starting material. The basic philosophy under which our Quality Control functions is that good quality must be manufactured into products; quality cannot be inspected into our products".

The Radio Corporation of America, USA, has issued a policy statement which reads as follows:

(a) The Quality Control organisation will provide service at the Somerville location to evaluate and advise on product quality and trends of purchased materials, in process operations, finished devices and customer returns.

(b) The Quality Control organisation advises Management on all matters pertaining to the quality of its processing and final product. In

addition it makes recommendations for improving quality, reducing scrap loss and decreasing cost.

(i) They will establish graphic Quality Control indicators in major production operations to assist the control of product.

(ii) They will report, formally and informally, major problems of a chronic or epidemic nature.

(c) Quality control will initiate and provide statistical assistance and participate with manufacturing in effecting corrective action for product improvement.

(d) The Manufacturing Department is assigned direct control by Management of building quality into the product and fulfiling the requirements of standard specifications.

BRITAIN

The Quality Control Department at Rolls-Royce, UK, has the responsibility to improve and maintain the quality of the product. The manner in which it has been built up, and its approach to problems, have been influenced by unusual circumstances which have been explained as follows:

(a) The product is a highly technical one demanding the utmost in reliability and integrity of components which are operated under conditions usually beyond normal experience.

(b) The Company has a long tradition of "quality" workmanship, in which large numbers of employees of all grades take an intense personal interest.

(c) There is a large, able and experienced Inspection Department which has operated successfully for many years, exercising a good deal of judgment, and functioning in many respects as a Quality Control Department in the commonly accepted sense.

(d) The aircraft engine embodies a large number of "bought-out" components. These include complicated and delicate accessories and controls which are usually "proprietary". This means that they have been designed, developed and manufactured by specialist firms, and supplied, ready tested, for incorporation in the engine as complete functioning units. Examples are the fuel control unit, various automatic and serve controls, actuators, oil coolers, and fuel heaters. Special difficulties arise because the manufacturers often have a narrow specialised technique and usually they lack the resources of the large engine firms. They have little or no direct contact with engine-users and so have only a limited experience of the behaviour of their products under service conditions.

Realising the great value of the tradition and experience and skill which exist throughout the factory, every effort has been made to preserve and take full advantage of these important assets, and not to stultify them by superimposing a rigid technical control.

In Joseph Lucas Ltd., UK, importance is attached to inspire operatives to do a good job. The basic intention of Quality Control is to make right first time and inspection is incidental to know that it has been made right.

The value of quality control to N. Corah Limited, UK, is explained as follows:

"When a customer buys a sweater for herself or a pair of socks for young Johnnie, she judges from the appearance, style and finish whether the garment looks its value. She also takes some things for granted and others on trust. She assumes, for example, that the garment is made correctly, that the colour and appearance will not change when she washes it, that it is of the size which it claims to be and that the socks are of equal length. She hopes that the garment will not shrink when it is properly washed and that it will wear as long as she thinks it should—the latter an arbitrary standard, perhaps, but one on which confidence in a branded name is established. She may consult the salesman, whether in fact she takes his advice or not.

"This individual appraisal multiplied millions of times each year, whether over the counter or later over the tea cups, provides the never ending test which manufacturers such as ourselves must pass if customers are to come back

a second time. Few of them can have any idea of what this imposes on a large-scale manufacturer of knitwear, or of the organisation required to meet the challenge. Before the war, the criterion to the customer for our class of garments was price. To us the quality and value which we were able to provide at the price was a matter of pride, but nevertheless, the factor of quality came second. Today the situation is reversed. Owing to the steady rise in the general standard of living, we have to face the fact that we are in a quality market in which, moreover, the acceptable standard is steadily rising. Standards which ten years ago seemed worthy of attainment have been passed and are already insufficient; as our quality improves the target recedes."

Though a few instances have been cited, in all the factories visited in Japan, USA, and UK, the management objective towards quality control activity was well defined and directives were issued for the implementation of the objectives. These were issued sometimes in policy statements as discussed above or as internal directives to the department.

Organisation & Functions

The views on organisational aspects in Japan expressed by the Quality Control Specialists' Study Team of Japan are reproduced below:

In general, the organisation of Japanese enterprises is not up to date, especially the organisation of the head office is out of date. In general, the power of the "line" is strong, while that of the "staff" is weak. But this is gradually being improved. There are still many troubles left even where there is a formal organisation if management has not been fully converted. In Japan, the purpose of Quality Control is to manage an organisation consisting of the "line" (such as the purchasing department, the production department, and the sales department) that carries out Quality Control and the "staff" that promotes, coordinates, and checks them. There are some companies that include the Quality Control section within the production department. Also a number of companies have a Quality Committee. This committee examines the drafts for general Quality Control education programmes within their company, the Quality Control education programmes for senior staffs, the five-year Quality Control project, or the project of promoting standardization. However, there are only a few companies that use the committee to carry out actual Quality Control activities such as the solving of quality troubles or the determination of the quality level, but there are a number of companies that have a committee just for the sake of formality.

Although many companies have such above-mentioned sections for the sake of formality, there are many wastes and troubles in their management because of ambiguous job specifications, responsibility and authority. Effort is being made in the Quality Control field to correct this situation to make a balance among standardization, quality, cost, and production volumes, and so to promote them up to the level of overall control. However, a problem in almost every organisation is that there is no quality manager.

Toshiba comprises the Main Office and 6 Divisions. Each Division has its General Affairs, Production Control, Quality Control, and Engineering Departments. Quality Control at Toshiba is carried out both by the committee organisation as described below and the Quality Control Departments of each Division.

The executive director in charge of production presides over the Central Quality Control Committee, and its members are either the managers of Divisions or assistants and the managers of the research laboratories. Policy concerning quality control is established and the condition of Quality Control in each division is reported to this committee. The Quality Control Staff Group submits proposals concerning problems brought up at the Central QC Committee, and also studies and applies new statistical methods, while the QCG (Quality Control Group) under it is a QC study group composed of young, enthusiastic engineers.

The Quality Control committee of each Division, under the Central Quality Control Committee, is presided over by the manager of the Division or his assistant, and decides on the policy of each Division according to the policy set forth by the Central Quality Control Committee, and passess it down the line. And so with

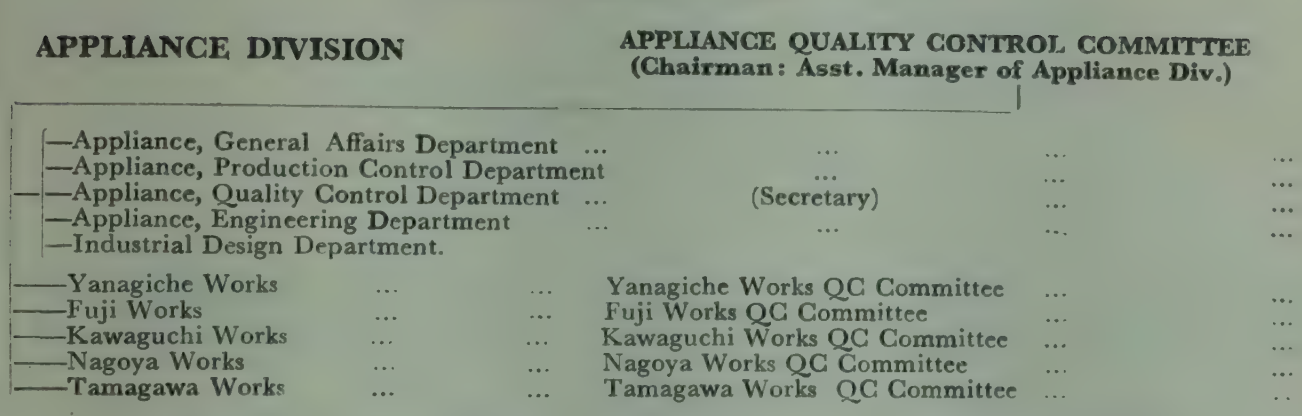


Fig. 1—Organisation Chart of the Appliance Division and its QC Committee (Toshiba)

the Quality Control Committee of each works, except that the problems taken up become more definite and everyday ones. Figure I shows the committee organisation for the Appliance Division.

It is only within these 3 or 4 years that Quality Control Departments or sections have been established in the Divisions and Works at Toshiba. This might sound somewhat strange, but it has been considered at Toshiba that true Quality Control should be carried out by the company as a whole, and so the Quality Control system was set up without changing the company organisation and letting Quality Control work within the company framework. Therefore, the line of authority remained the same as the company organisation and each Engineering or Manufacturing Section which already existed came to adopt the new useful techniques to carry out their responsibilities.

The techniques of Quality Control became rather widely used among the divisions in routine work, so each division and works recently set up either a Quality Control department or section which have come to take up such duties as the compiling and reporting of quality information, dealing with complaints, and quality control education and training. The thought behind this is based upon the fundamental principle that Quality Control is not something which the Quality Control Section alone carries out, but that fruitful results may be obtained through company-wide effort towards fulfilling the responsibility towards quality [this is clearly stated in clause (d) of the Quality Control Policy Statement]. Such a point of view completely agrees with the concept of Total Quality Control which is becoming widely discussed recently.

The organisation charts of Eastman Kodak are shown in Figure 2. It will be noticed that the Quality Control Manager reports directly to the Vice-President. The Quality Control Department is divided into 3 main sections which are shown in Figure 2A. Figure 2B shows the department-wise Quality Control organisation. Figure 2C explains the functions of the product Quality Control Engineer.

Under services in Figure 2B are listed sections whose services are available to all departments.

In Bristol-Myers Co., USA, the Quality Control programme has been developed on the following four lines:

(a) Inspection of all incoming raw materials to determine that they meet a high acceptance level of purity.

(b) In-plant process inspection to assist the manufacturing operations in finding and preventing trouble spots, and in determining how quality production can best be accomplished.

(c) Inspection of all packaging materials to ensure that they meet the various physical specifications which are necessary to our packaging machine operations.

(d) Overchecking outgoing production and products from the field so that we can be sure that we are, in fact, achieving our basic goal.

The responsibility for achieving the above

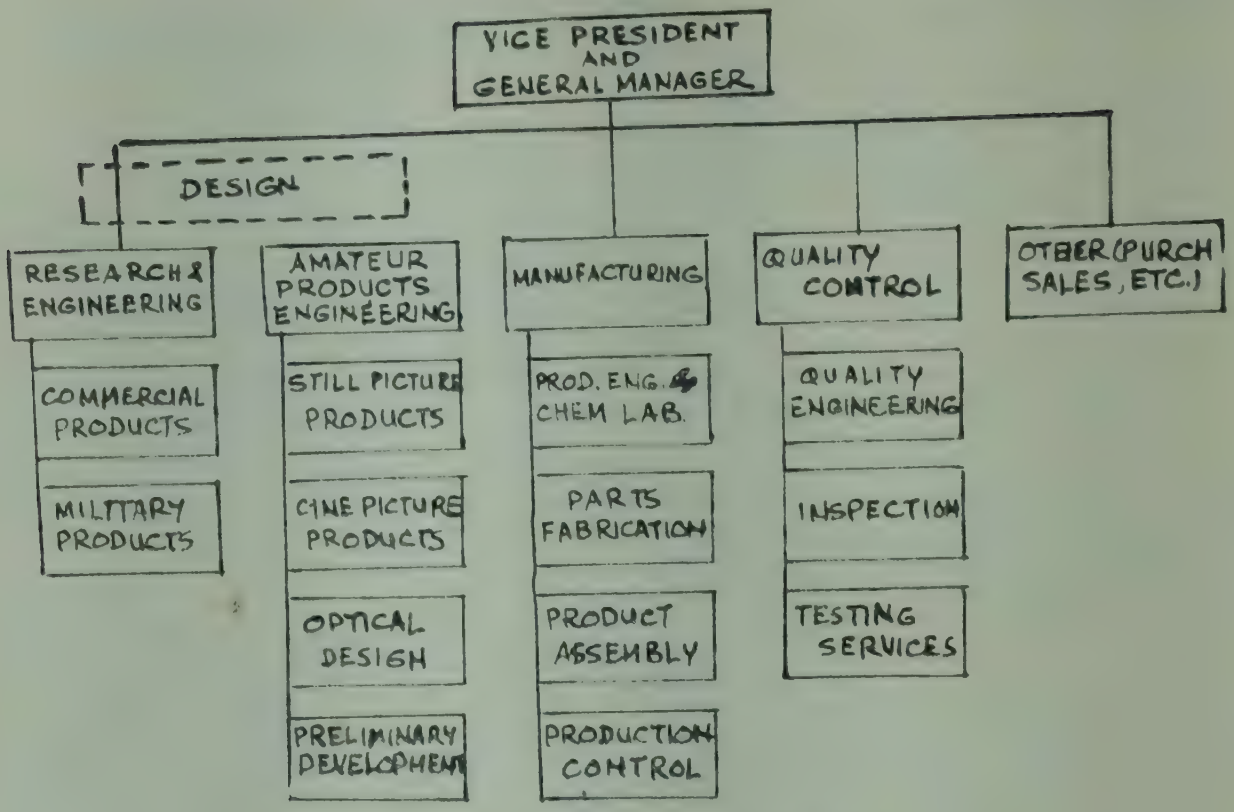


Fig. 2A—Quality Control Department

QUALITY CONTROL ORGANIZATION

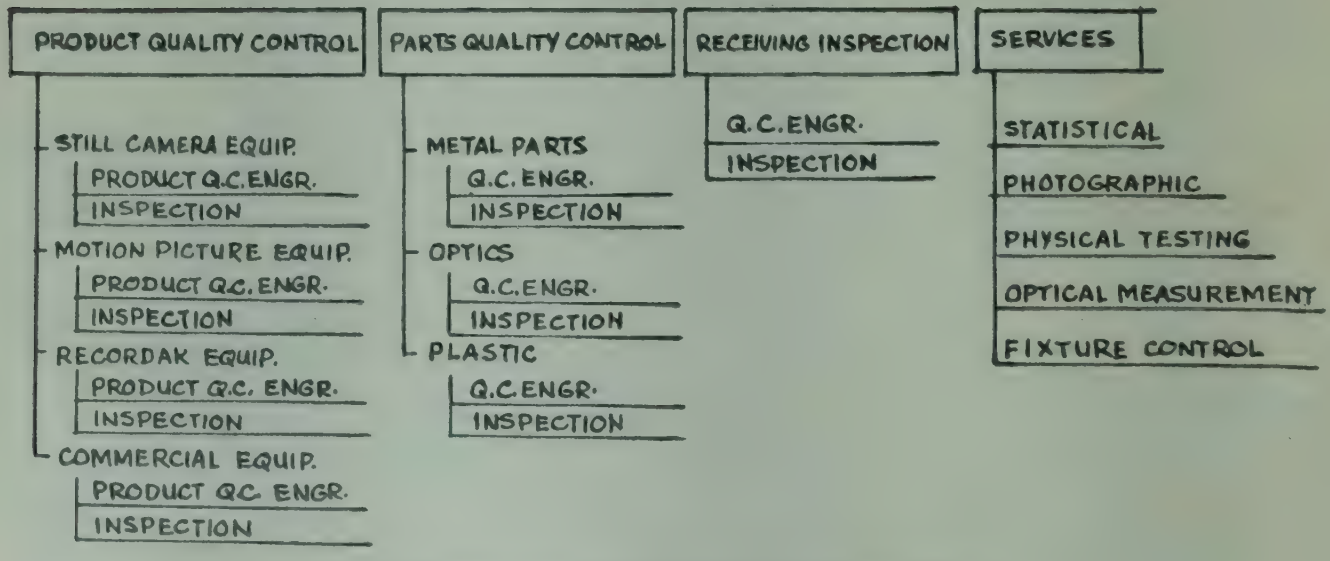


Fig. 2B—Department-wise Quality Control Organization

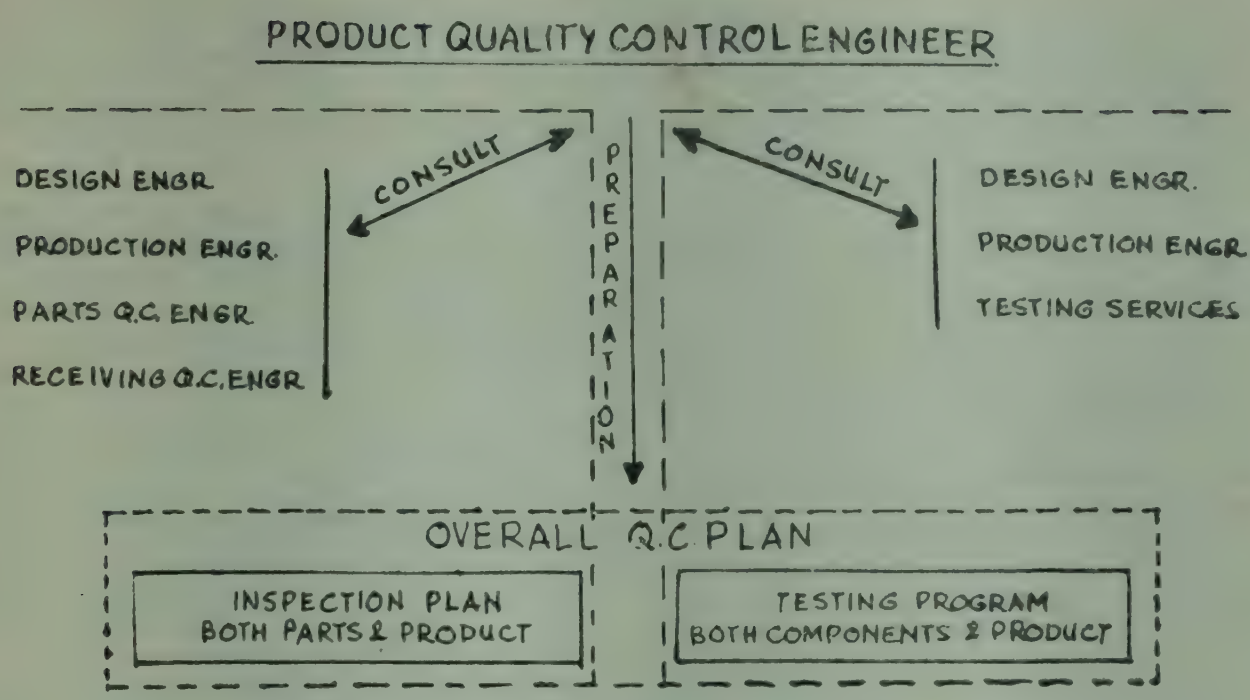


Fig. 2C—Functions of Product Quality Control Engineer

aims is divded into three groups; the Quality Control department, the purchasing, inspection and specification department, and the statistical services department. All these three sections come under Director of technical services (Organisation Chart shown in figure 3).

The Quality Control Manager at Singer Manufacturing Co., USA, who reports to the plant Manager, has under him three divisions: Inspection, Engineering and Administrative. In addition, they have a Quality Service section at the head office in New York, whose job is to study

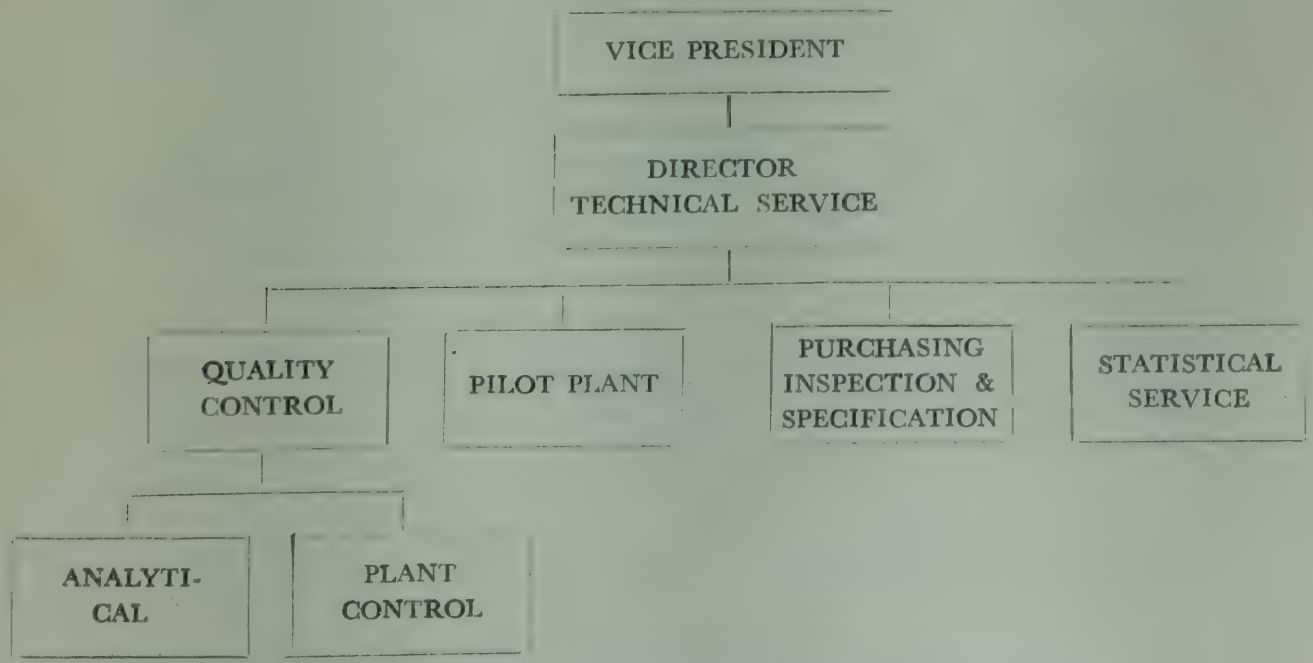


Figure 3—Quality Control Department, Bristol Myers Co., USA

the problems regarding quality of their products in their various divisions and plants throughout the world. This is done by visits to sales organisation of their company and by studying the products of their competitors. Their main aim is constant feedback for improvement.

The chiefs of inspection, quality engineering and administration report to the Quality Control Manager. The detailed organisational set up is shown in Figures 4A, 4B and 4C. In Inspection department there are Quality Control supervisors who look after the quality problems. In case of difficulty they turn to the quality engineering department. The quality engineering department works out the quality control procedures and supplies the necessary techniques. This department, besides the chief Quality Control engineer, consists of three Quality Control engineers (one of whom is a statistician), two statistical quality control analysts and nine technicians who work for them, and a feedback analyst. He is responsible for all analysis and suggestions for corrective action. He has clerical assistance. The Administrative section looks after budget requirements, manpower, personnel problems and technical correspondence.

In Rolls-Royce Co., UK, the Quality Department works by encouraging the Shop personnel and the Inspection Department to maintain their initiative, helping them on the more fundamental problems, and in particular by concentrating on the basic quality task of:—

(a) Assessing the limits of variability permissible.

(b) Assessing the variations likely to occur throughout a production run.

(c) Taking steps to bring the variance to an acceptable level.

The Rolls-Royce Quality Department consists of four main groups:

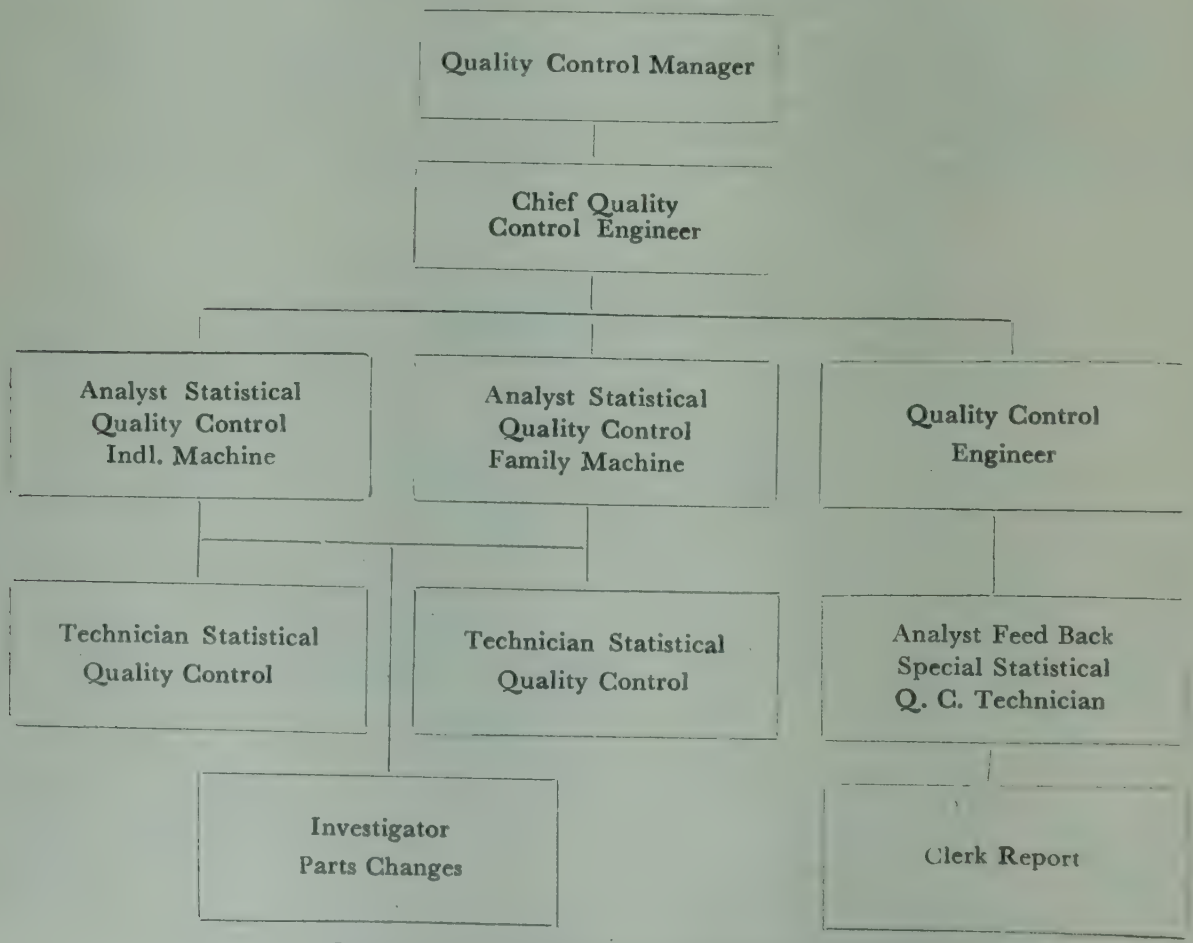

Quality Control Manager
Chief Quality Control Engineer
Analyst Statistical Quality Control Indl. Machine
Analyst Statistical Quality Control Family Machine
Quality Control Engineer
Technician Statistical Quality Control
Technician Statistical Quality Control
Analyst Feed Back Special Statistical Q. C. Technician
Investigator Parts Changes
Clerk Report

Figure 4 A—The Singer Manufacturing Co., USA

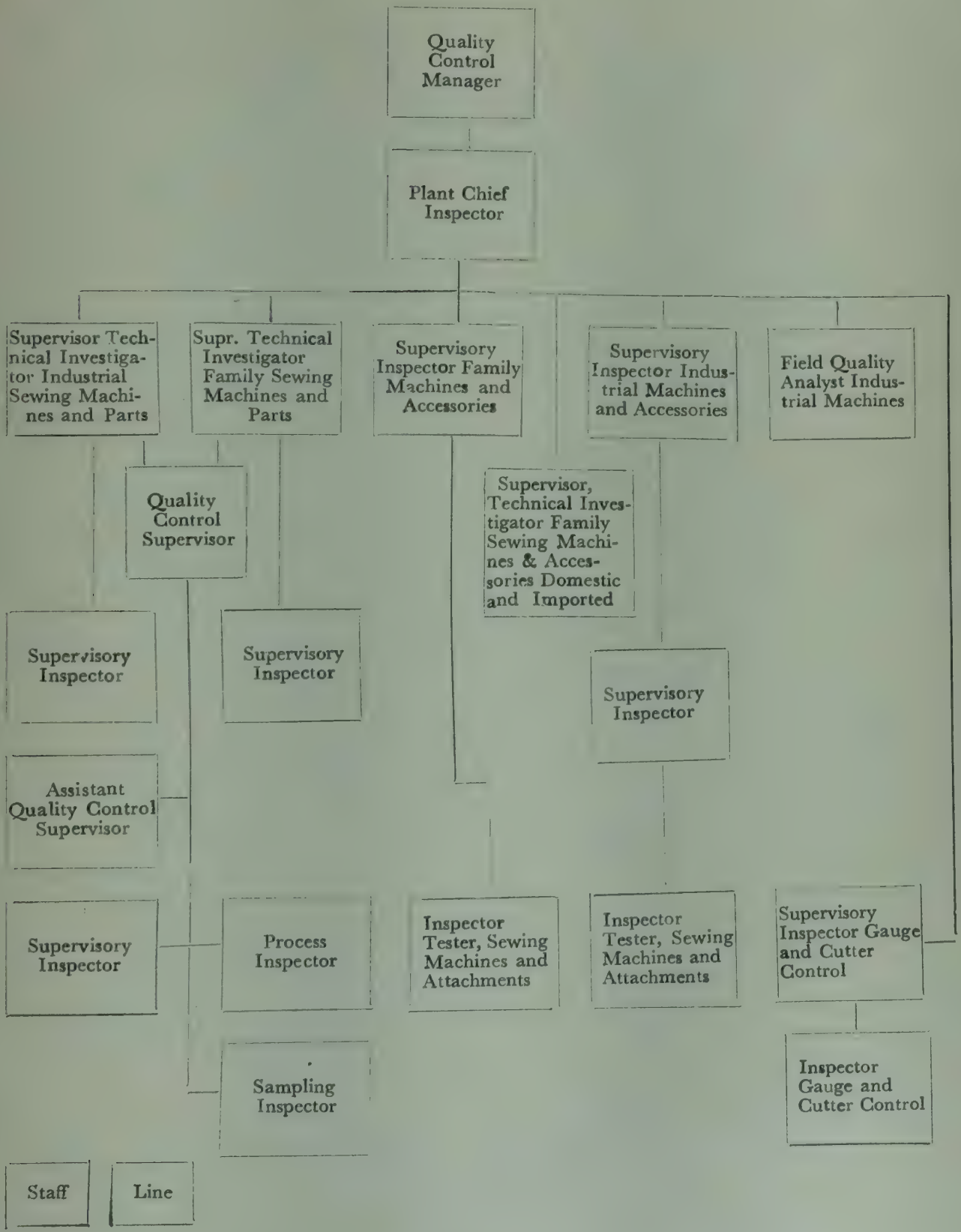

Quality Control Manager
Plant Chief Inspector
Supervisor Technical Investigator Industrial Sewing Machines and Parts
Supr. Technical Investigator Family Sewing Machines and Parts
Supervisory Inspector Family Machines and Accessories
Supervisory Inspector Industrial Machines and Accessories
Field Quality Analyst Industrial Machines
Quality Control Supervisor
Supervisor, Technical Investigator Family Sewing Machines & Accessories Domestic and Imported
Supervisory Inspector
Supervisory Inspector
Supervisory Inspector
Assistant Quality Control Supervisor
Supervisory Inspector
Process Inspector
Inspector Tester, Sewing Machines and Attachments
Inspector Tester, Sewing Machines and Attachments
Supervisory Inspector Gauge and Cutter Control
Sampling Inspector
Inspector Gauge and Cutter Control
Staff
Line

Fig. 4B—The Singer Mfg. Co., USA

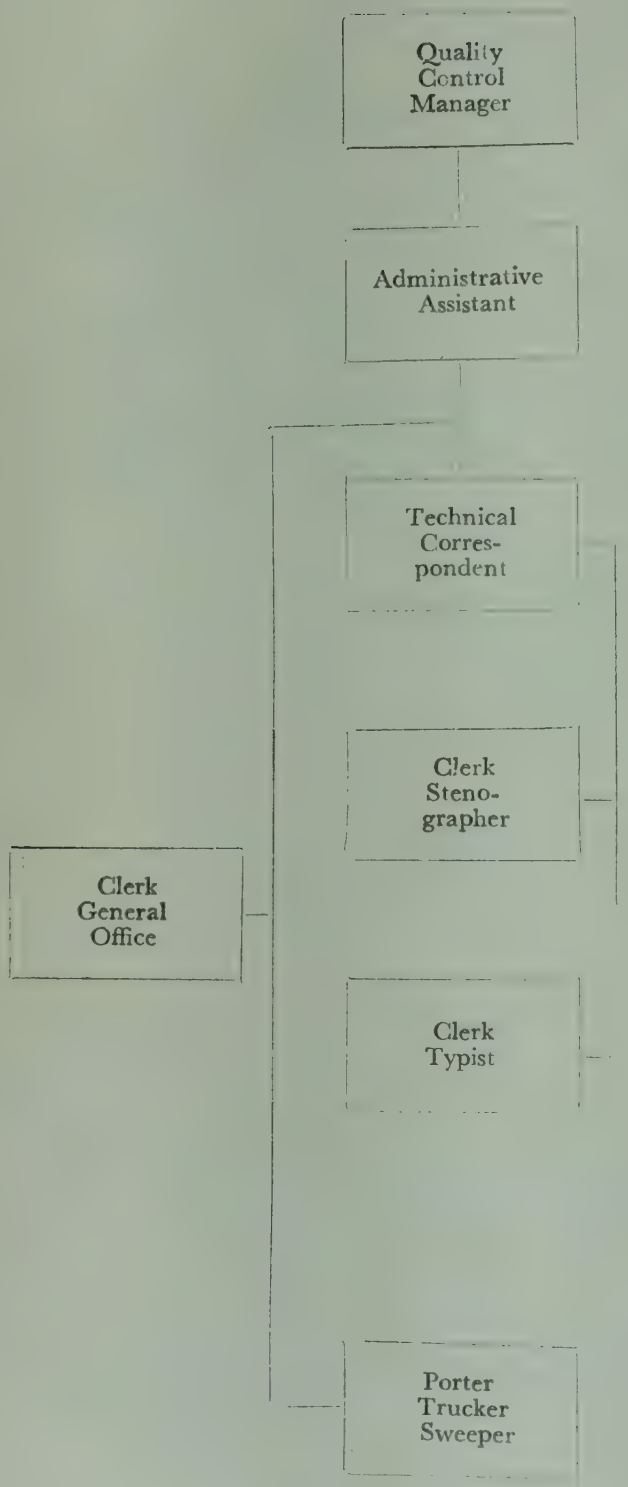


Fig. 4C—The Singer Mfg. Co., USA

(a) *Front Line*: This team concentrates on day-to-day problems arising on the shop-floor. It endeavours to assist Production and Inspection by finding short-term answers to problems as they arise.

(b) *Rig Testing:* The establishment of safe standards of acceptance, e.g., of finish, of non-metallic inclusions, of welds, etc., and the detection of potential weaknesses, requires fatigue tests on a sufficiently large sample to enable the full production variance to be studied. This work differs from that of Development and Laboratory in that these departments have established a specification standard on a Type specimen, e.g., by a Type Test, and it becomes the task of this Quality group to define the tolerance and in particular the "bottom limit" of that specification.

Simple machines have been developed to testimulate working conditions on the components under investigation, and valuable results have been obtained. These rigs are operated in two shops—at Derby and at Hucknall.

(c) *Non-Destructive Testing Development:* The gas turbine engine has introduced many new problems of flaw detection, and during the past three years considerable progress has been made in methods of non-destructive testing. Greatly superior crack penetrants, magnetic particle methods, and ultra-sonics are now in continuous use.

(d) *Metrology:* This group investigates, assesses and where necessary, develops measuring equipment for the Inspection Department. It also carries out detailed measurements of bought-out components such as ball and roller-bearings, governor pumps, and the like, where dimensional accuracy is vital, as a sampling check on supplies.

The breakdown of Quality Control function at Massey-Ferguson Tractor Co., UK, covers the three functions, the dimensional and functional side with Inspection; the metallurgical and chemical side with the Production Laboratories; and customer acceptance with Product Quality. (Organisation chart is shown in Figures 5A and 5B).

PLANT ORGANIZATION CHART

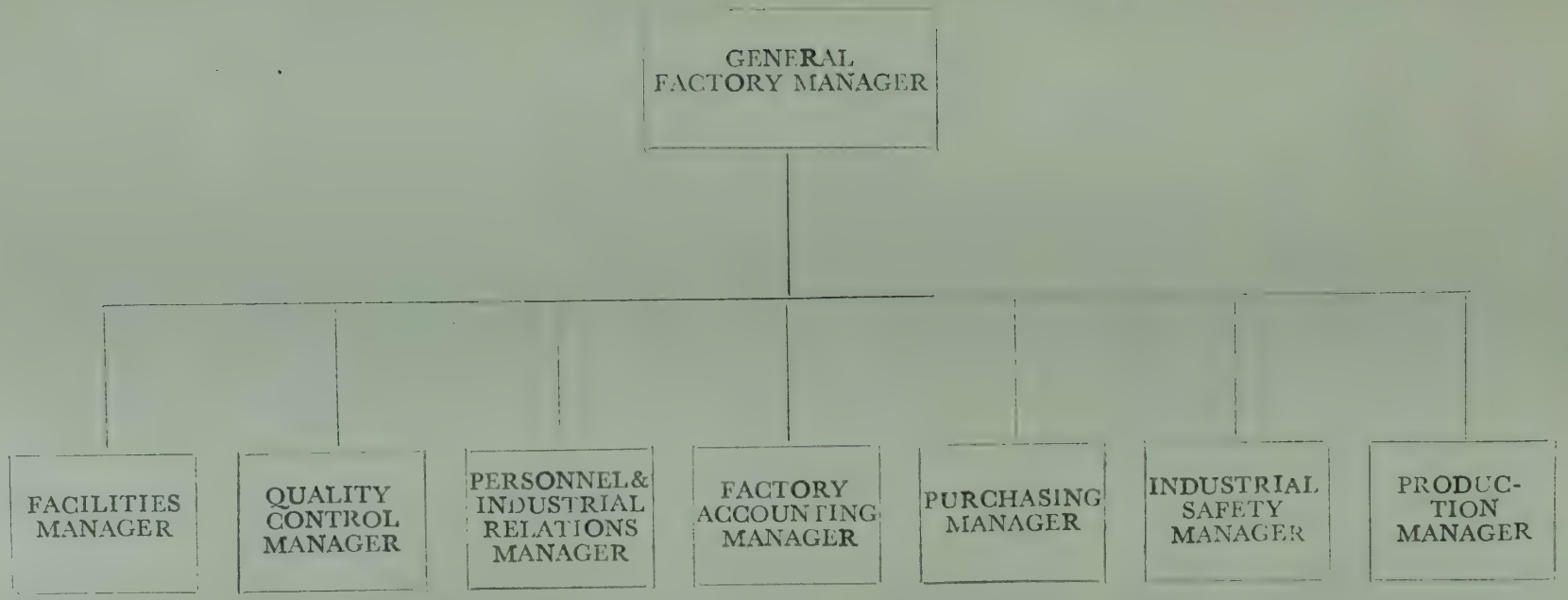


Fig. 5A—Massey-Ferguson Tractors Ltd., UK

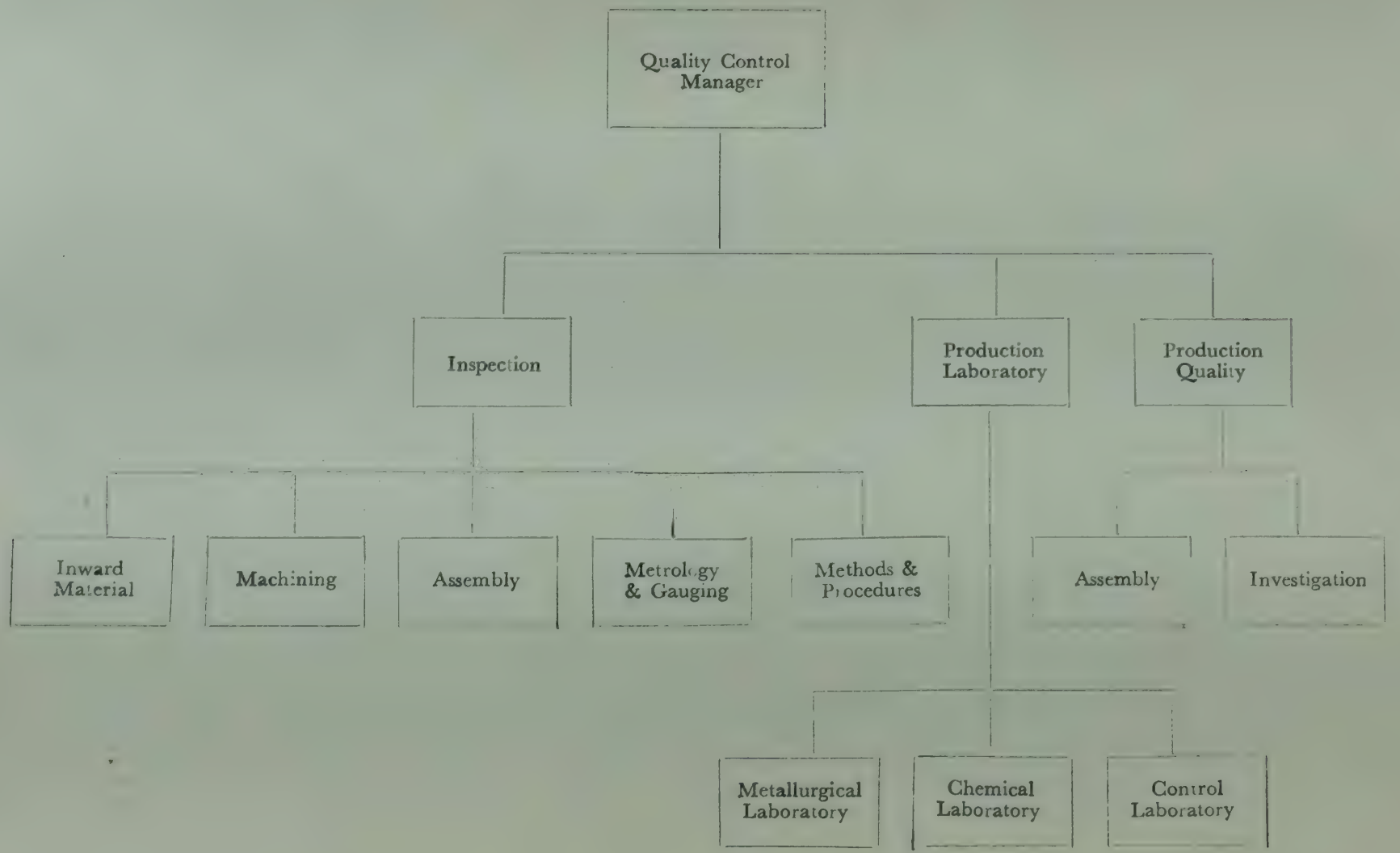


Fig. 5B—Massey-Ferguson Tractor Ltd., UK

Inspection is then divided into the line side controlling raw and bought-out material, machining and assembly, and the staff or facility side comprising Metrology and Gauging, Methods and Procedures. Each side is of equal importance, the line side being responsible for the control of quality with all the resultant decisions on acceptance or rejection, whilst the facility side has the responsibility for the provision and maintenance of adequate tools, equipment and procedures to enable the work to be carried out efficiently.

The Production Laboratory divides in a similar manner, with the Metallurgical and Chemical Laboratories acting as a facility and providing a service on request, and the Central Laboratories for heat-treatment and process carrying out a line operation and responsible for the quality of the product.

Product Quality has the direct responsibility for assessing and investigating any service troubles, and a general responsibility to Quality Control to ensure that the necessary line action to rectify these faults is taken through Inspection and Production Laboratory channels.

The Quality Control Manager expressed his views against splitting the Statistical Quality Control Group from Inspection. The dimensional and functional side of control is the responsibility of the Chief Inspector, who today must be both analytical and statistical in his approach, besides being a sound engineer. Statistical Quality Control must drop into his rightful place as a vital control tool.

Quality control in N. Corah Ltd., UK, is organised as a technical service department. As the company explained: "It was given no executive function but was there to be called in when the production departments ran into problems which they were unable to solve quickly. Its members had all-round technical experience of the industry and, what was equally important, the time to study in detail any problem passed to them. Because they were outside the departments they could often see implications which eluded managers who were too close or too familiar with them. Their free access to departments also meant that they could prevent the latter from becoming too watertight and parochial, and more than once it was found, through the operations of quality control, that the solution to one department's problem had already been solved in another without the former getting to hear of it. The fundamental purpose of quality control is to standardise materials, achieve their manufacture by standardised methods, and to set a high but attainable standard for the ultimate products."

From the above discussions it will be observed that quality control functions occupy high status and head of the department generally reports directly to the Chief Executive in the Organisation. In most of the companies visited, they have put down in writing the functions, duties and responsibilities of the quality control department. Appendix F contains such lists for Western Electric Co., RCA and Bausch & Lomb Inc. of USA.

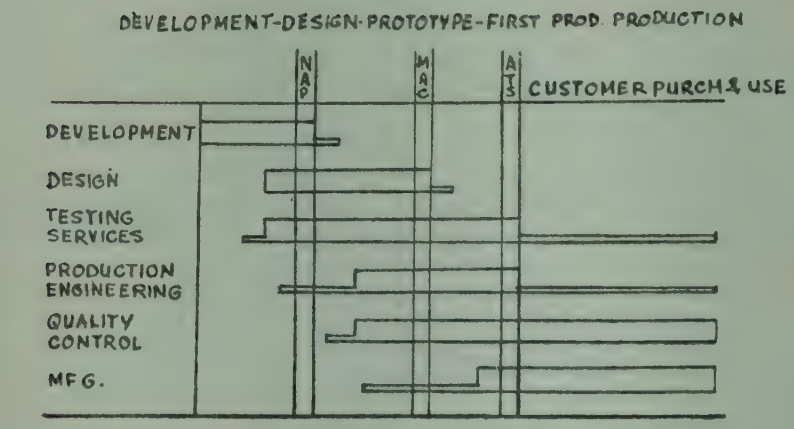
New Products Development

One of the important functions of quality control in Eastman Kodak Co., USA, is in connection with the development of new products. Whenever a new product is to be developed, quality control department remains regularly in touch right from the initial stages with the development and design departments during the process of development and when the development is completed, the quality control department making use of the testing services evaluates the prototype for its compliance with the functional performance as specified by Market Research or Sales department.

If the quality control department is satisfied and approves the prototype, it is cleared and passed on to the Manufacturing Department for tooling. When tooling has been designed by this department, the quality control department with the help of testing services again checks it for correctness of tooling in order to get consistent production to required quality standards and if found satisfactory gives approval for series production and shipping by the manufacturing department. This function of quality control in Eastman Kodak is explained in Figures 6A, 6B & 6C.

Corrective Action

In industries in Japan quality control committees play an important part in taking corrective action. These committees exist at various levels in an organisation. In small factories in Japan the inspection department performs the function of quality control under the overall



NAP - NEW APPARATUS PROPOSAL
MAC - MANUFACTURING APPROVAL CARD
ATS - APPROVAL TO SHIP

Fig 6A

TESTING PROGRAM FOR PRODUCT EVALUATION

ENGINEERING SAMPLE SUBMISSION
- A. PROTOTYPE STAGE
  1. FUNCTIONAL TESTS
  2. TYPE TESTS
  3. RELIABILITY EVALUATION

MANUFACTURING APPROVAL CARD
- B. FIRST-FROM-PRODUCTION STAGE
  1. QUALITY EVALUATION
  2. TYPE TESTS
  3. RELIABILITY DEMONSTRATION

APPROVAL TO SHIP

Fig 6B

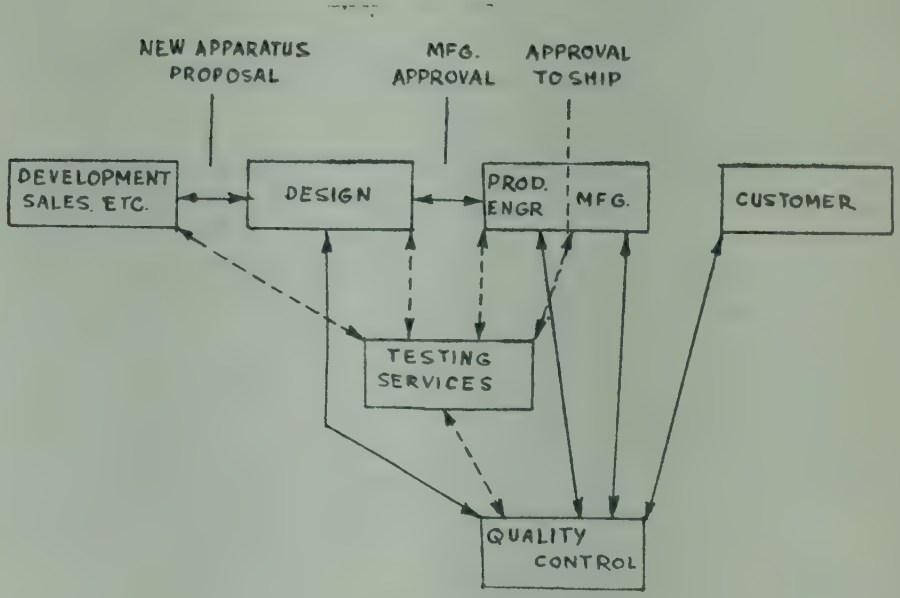


Fig 6C

Fig 6 (A, B & C)—Quality Control function in Eastman Kodak Co., USA

guidance of the quality control committee presided over by the plant manager. In almost all the industries in USA, the quality control department performs an advisory function, which of course, cannot be ignored by other departments. The action is always instituted through the production department.

In Singer Manufacturing Co., USA, the weekly and monthly analysis of processes are sent to the production managers and a reply as to the actions taken should be intimated within seven days. When the answers are received they are scrutinised by Quality Control Analysts. In case they are not satisfactory, further investigation is instituted.

In Lockheed California Co., minor actions are taken on the shop-floor. Other matters are discussed in Material Review Board, including acceptance or rejection of incoming materials.

Evaluation

The evaluation of Quality Control work was not attempted in any of the industries visited in Japan, USA and UK. The reason for this was that most of the factories considered the quality control as an essential management function and there was no doubt as to its usefulness. Some practices regarding the evaluation of quality control programme are discussed in subsequent sections.

The evaluation of quality control programme at Western Electric Co., Allentown Works, USA, is reproduced from literature supplied. "A considerable amount of money has been invested since 1952 in Quality Control Engineering, training and process checking. Have we received an adequate return from this investment? How many dollars have been spent? How many tangible dollars have been saved? Do continuous controls pay off over the year?" These are management questions which must be answered if quality control is to thrive and find its rightful place in industry.

One yardstick used successfully at Allentown is the comparison of junk, repair and sorting costs, called Merchandise Losses, with the value of good product manufactured each month. These dollars of merchandise loss, kept track of by the Accounting Organisation, include the cost of labour, materials, and overhead invested in each piece of product up to the process point where it is discarded. They also include the labour costs expended in repair and sorting operations which are not normally a part of the manufacturing process. The dollar losses for each product line are summarised monthly and then divided by the dollar value of product stocked during the month, providing a "loss per dollar stocked" figure. A "loss per dollar stocked" control chart is maintained for each product line and for the entire plant. This is a positive management report showing the monthly picture of past performance for comparison with current results.

For example, on the Switchboard Lamp job, the reduction of merchandise losses, using 1951 as a base period, portrays the steady and continuing progress made in reducing losses since the introduction of an intensive Statistical Quality Control Programme. As was mentioned earlier, this was a well-established product in manufacture for over 50 years. Current monthly losses in 1959 are averaging only 13% of the 1951 level. Total Allentown Works losses show a similar improvement picture over the same period. The slight increase in 1957 losses was due to the introduction of new semi-conductor devices and travelling wave tubes with higher start-up losses. The established production lines representing 92% of total output continued to make progress as shown by the dotted lines for the last three years. Results to date for 1959 indicate that the forecasted improvement will be achieved despite a rising programme involving new personnel and increased production pressures. These charts, of course, reflect total improvement which is attributable to other things as well as the use of Statistical Quality Control. However, of the total plant picture, almost 50% of the improvement since 1951 can be directly tied to the Statistical Quality Control Programme.

Quality Costs

A measure of quality costs can be made by comparing these costs with plant output (Fig. 7). Three years of comparable output are 1952, 1956 and 1958. The quality costs for these three years are 8.4%, 6.4% and 5.9% respectively, showing a steady reduction. It can be seen from the chart that quality costs tend to vary inversely with fluctuations in production levels. This is a natural phenomenon, since Quality Control Engineering and Inspection effort cannot always be proportionately sacrificed as production is reduced.

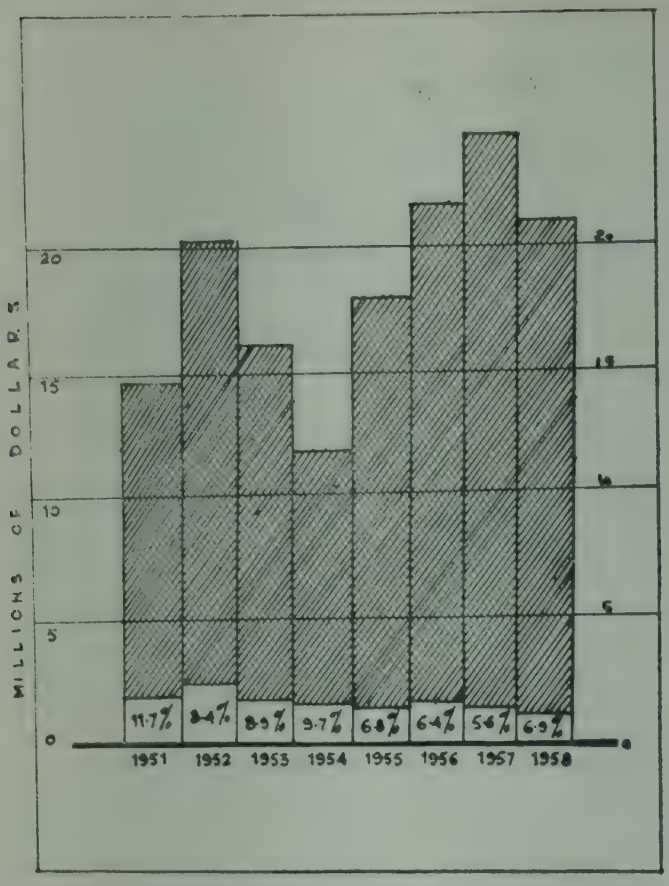


Fig. 7—Quality costs compared with total Output at Allentown Works

Fig. 8 shows a breakdown of the quality costs. In 1951, prior to the intensive use of Statistical Quality Control for process control, we had Inspection Methods Engineers who provided consulting service to Product Engineers who reported to the Inspection Department and were used as engineering trouble shooters to investigate serious shop problems. Both of these engineering groups were combined in 1952 to form the Quality Conrol Engineering Department. The precentage of this engineering effort to plant output has remained relatively constant for comparable output years.

Prior to 1952, a form of process control existed using patrol or roving inspectors to make random checks at key processing operations. These inspectors reported to the Inspection Organization and did not use modern Statistical Quality Control techinques. With the introduction of the control chart for process control, the patrol inspectors were gradually transferred to the shop as process checkers. The process checker takes samples, makes measurements and plots charts in accordance with Process Control Layouts provided by the Quality Control Engineer. Process checking costs have remained fairly constant over the past several years despite substantial increases in control chart coverage. This was accomplished by Quality Team diligence in extending process checking intervals as causes of variation were eliminated. It should also be noted that these costs were not really an addition, but merely a reassignment of effort to a more scientific procedure.

Inspection costs have been markedly reduced from 9% in 1951 to 3.4% in 1958. This reduction is almost entirely due to the application of modern statistical quality control practices. Sampling plans were improved to provide adequate protection at minimum inspection cost. Good process controls improved product quality flowing to inspection, thereby making it possible to progressively reduce the size of inspection samples.

A comparison of these cumulative quality costs since 1952 with the tangible dollar savings in Merchandise Losses and Inspection Costs is shown in Fig. 9. The Quality Control Engineering cost includes overhead and total costs of the 22,636 hours spent in formal training classes. The cost of this group, which provided the statistical know-how to aid the shop and product engineering in refining the processes through team effort, can very realistically be considered the basic quality cost of the savings shown. The cumulative Merchandise Loss savings represent only that portion directly attributable to Statistical Quality Control. Reductions due to new processes and product designs from purely technical and design engineering efforts have been excluded.

These savings in Merchandise Losses and Inspection Costs played a major role in a substantial reduction of the costs of our products since 1951. Fig. 10 shows this effect by pricing out the 1958 programme at both 1958 and 1951 costs for those products which have been in continuous production since 1951. The actual cost of these Allentown products has been reduced by more than 30%. If we consider the effects of inflation since 1951 on present costs, the cost of all these products has been more than cut in half. These savings and similar cost reduction efforts throughout the Western Electric Company are a very real contributing factor

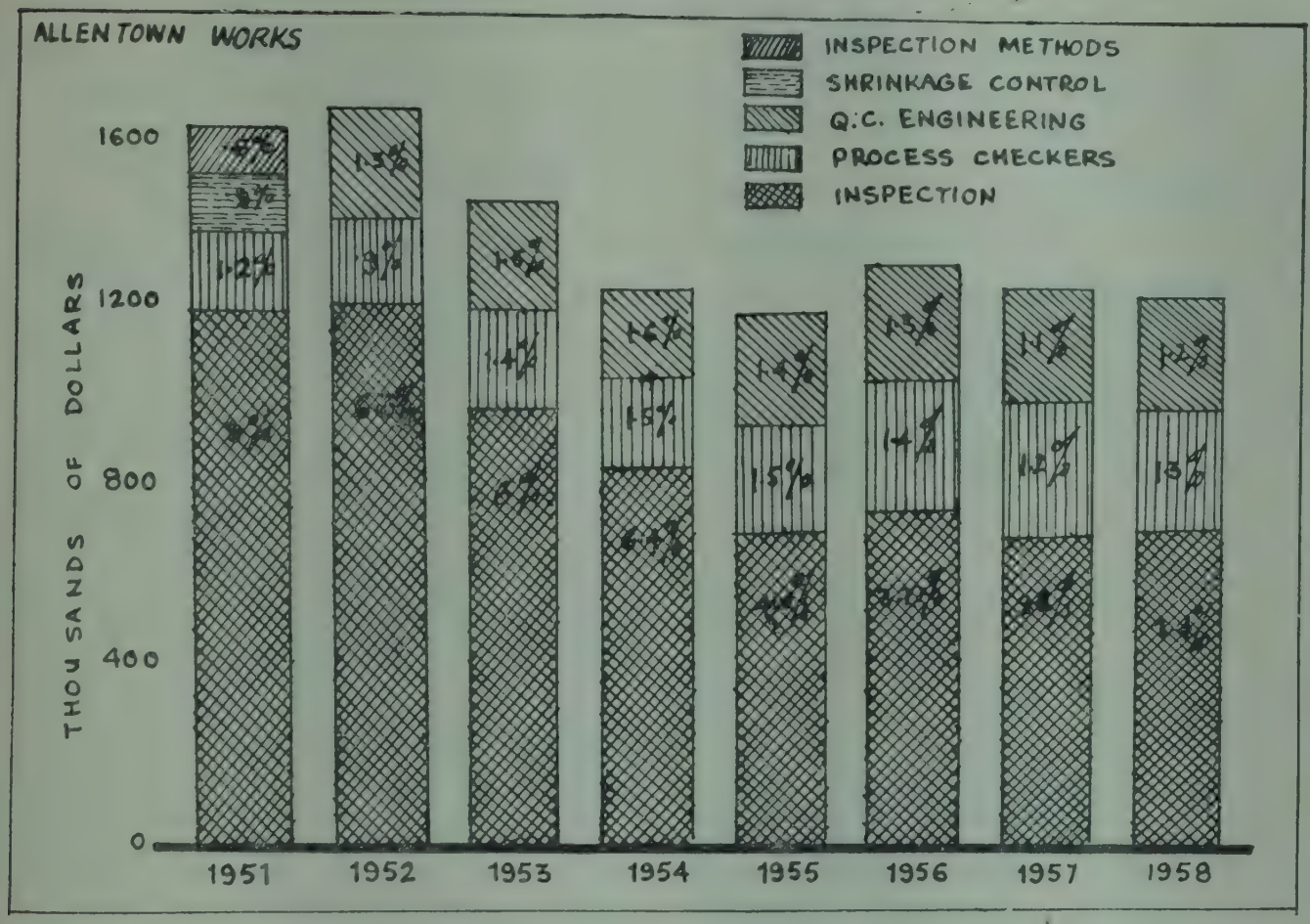


Fig. 8—Cost of Quality Control (Loaded)

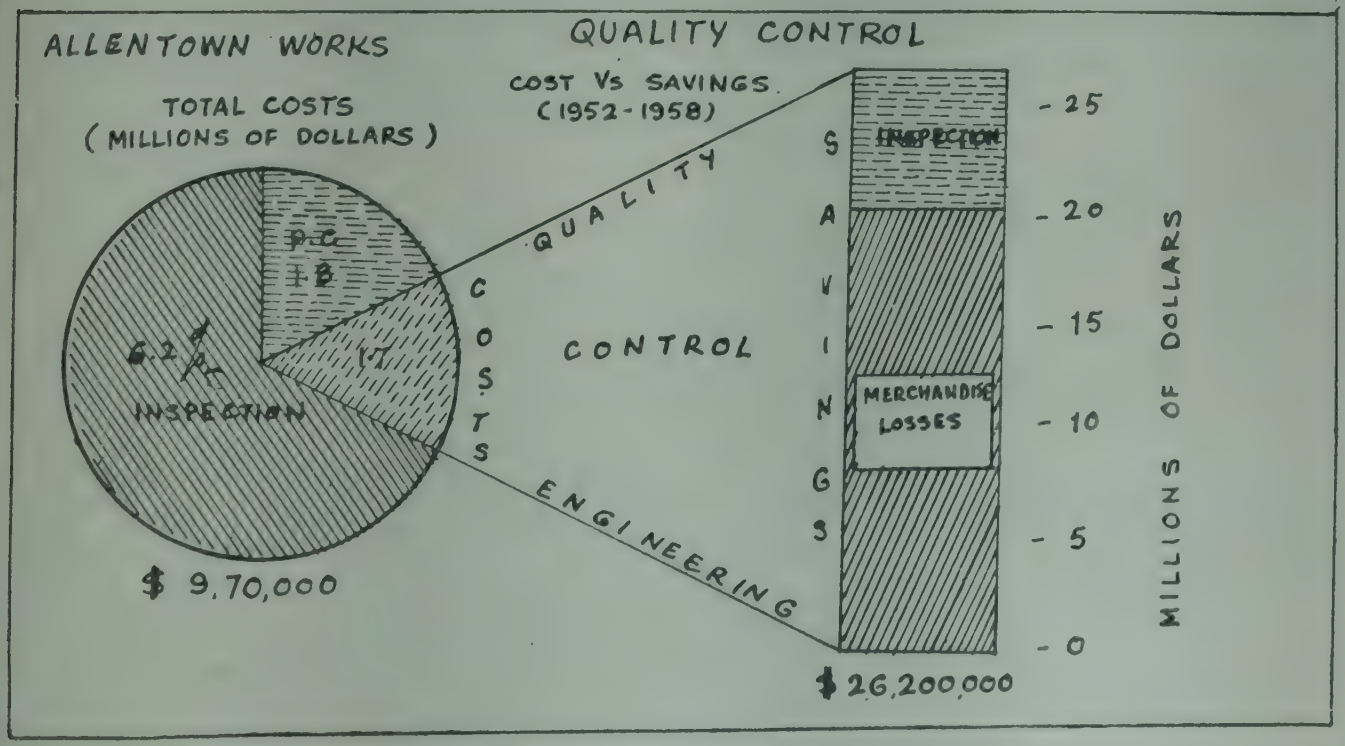


Fig. 9—Cost vs. Savings (1952-58), Allentown Works.

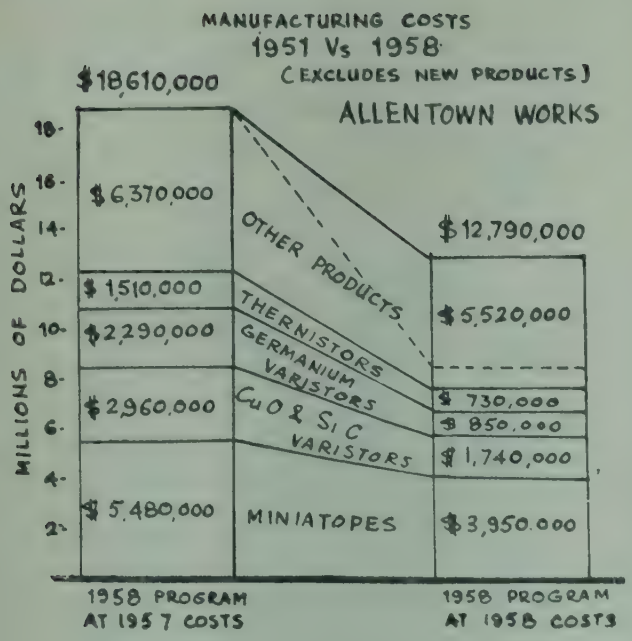


Fig. 10—Manufacturing costs (1951 vs 1958)

to keeping telephone rates far below the normal inflationary trend.

None of these dollar savings has been achieved by sacrificing the quality of finished products, on the other hand, this quality has steadily improved as shown in Fig. 8. The Demerit Index, a quality rating to customer standards, is another yardstick by which management measures the effectiveness of its Quality Control programme. The Allentown Works' overall Index (Fig. 11) shows consistent and steadily improving results.

Benefits

The President of the Toyo Rayon Co., Japan, has reported the following achievements of Quality Control:

(a) Percentage of first grade products was increased from 80% to 97-98%;

(b) The spinning speed gradually increased by 20-30% without reducing the percentage of first grade products; and

(c) It became possible to increase the number of pinholes of a spinneret to 7000-10,000.

Tohoku Works Ltd., Japan, a small-scale enterprise employing about 250 people, have been able to reduce the cost of bad quality (loss due to defects/number of products) from about 12 units in 1953 to 3 units in 1957; at the same time the labour productivity index has increased from about 140 in 1953 to 300 in 1957.

In the literature supplied at Western Electric Co. Allentown, USA, while presenting some significant milestones, we have for 1956:—

"Merchandise Loss reduction due largely to Statistical Quality Control necessitates plantwide interim bulletin revision effective January 1957. Average's 14% cost reduction with $4,000,000 annual savings".

Tangible results at Western Electric during past nine years are:

(a) A 70% reduction in merchandise losses;

(b) A 60% reduction in Inspection Costs;

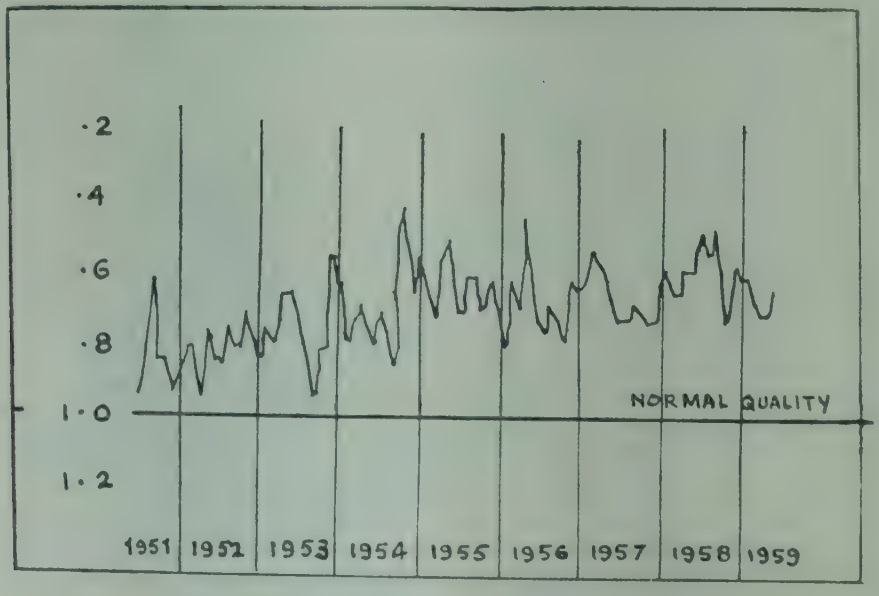


Fig. 11—Quality Index at Allentown Works

(c) A 50% reduction in customer complaints; and

(d) No quality rates out-of-control since September, 1954. Represents over 1100 consecutive monthly ratings for 67 months.

In Bausch and Lomb Inc., USA, it was mentioned that generally quality losses exceed prevention and identification costs. As an instance, it was explained that in instruments division alone, about 10 years back the quality losses were $600,000; now it is $200,000 and during this period production has doubled and quality losses have not entirely left pace with increased production.

Joseph Lucas Ltd., UK, have found (*Time and Motion Study*, October, 1961) that as a direct result of instituting a quality control system at a cost of £1,000 they saved £228,000 a year in scrap, rework and inspection.

The Directors' report of the N. Corah Ltd., regarding Quality Control says, "the quality may not have achieved the ultimate in perfection, but today our standards are higher than they have ever been while our losses from rejected goods are kept at a minimum".

The benefits of a Quality Control programme in a few factories visited have been mentioned above. However, it should be emphasised that in every factory visited, substantial achievements of improved quality, increased production, reduced cost per unit, reduced customer complaints were noted and the managements were aware of the same.

Personnel

The discussion regarding personnel for quality control was not possible in all the factories, visited in Japan, USA and UK. Some views and observations are described below.

During the meeting with experts in the field of Quality Control in Japan the personnel for Quality Control was discussed. It was felt by the experts that an engineer or a technical person, because of his better insight into problems involved and because of considerable prestige and power enjoyed by him in the industrial organisations, can provide more effective leadership in the introduction and implementation of Quality Control programmes.

The technical and managerial aspects of quality control work is carried out by Quality Control Engineers in USA. Under this designation there are persons with academic qualifications in statistics. This set-up was seen in most of the firms in USA like Singers, Bristol-Myers, Eastman Kodak, Bausch & Lomb, Western Electric and RCA.

The American Society for Quality Control in a policy statement on Professional Certification has said "the professional grades are to be earned by a member independently of the present membership grades specified by the constitution of ASQC. These present membership grades specify only minimum requirements as to education, age and amount (or time) or experience. It is the purpose of the professional grades to go beyond these requirements and certify as to the member's ability or proficiency in performing work at a given professional level. Ultimately it is planned to merge the time and experience requirements of the membership grades with the performance requirements of professional certification into a single, unified system. Before professional certification is feasible it is necessary to establish professional standards of performance against which individual performance can be measured. As a first stage in establishing such standards, it has been necessary to delineate the nature of quality control work. This has been accomplished in the paper "Basic Work Elements of Quality Control Engineering" (Reproduced in Appendix D).

The American Society for Quality Control in describing the basic work elements of Quality Control has emphasised the new approach involved in Quality Control Engineering, "The activity which ties together and directs the planning, control, evaluation and reporting of all the quality aspects of the production task is truly engineering. It is characterised by creative work. Statistics, technical process and product knowledge, and practical shop experience are combined in attaining the goal of optimum quality products at lowest possible cost. ..... To accomplish this objective, every producer needs an integrated programme for the control of product quality including its reliability elements comprising the basic work elements described herein, (see Appendix D). To totality of the work elements is not, of course, intended to describe the work of any single Quality Control Engineer, nor the work of any particular Quality Control Organisation. A Quality

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Control Engineer may specialise in only one or a few of these elements and still be performing legitimately professional work. Quality Control Engineering encompasses the planning, the control, the evaluation and the reporting of all quality aspects of the product from its conception through manufacture, processing, storage, delivery, installation, maintenance and repair to the end of its service life."

With the new approach to Quality problems the emphasis for senior and managerial posts in industries in USA, is technical ability in terms of product understanding and shop-floor experience, statistical knowledge and managerial competence.

Quality Consciousness

Generally speaking, the quality consciousness amongst employees was high in all the factories visited in Japan, USA and UK. For instance in Bausch and Lomb Inc., in USA, it was explained that quality mindedness was a tradition and is high in their factory.

Suggestion schemes were in operation in most of the plants visited abroad. In Bausch and Lomb Inc., a poster was seen which read as: "Is there a better way? No matter how good we are we can always find a way to be better. What can you do to speed operations, improve quality, cut costs and improve records for good services?"

It was however pointed out at a Singer Plant in USA, that unless the processes developed and have come to a state of normalcy in a particular plant it is no use introducing the suggestion scheme as in that case there will be plenty of suggestions which may already be on the programme of the company.

In many factories visited abroad, particularly in USA, slogans were displayed prominently. Some of the slogans displayed at the Singer Plant in USA are shown below.

In addition to the suggestion scheme and slogans, in some factories quality performance was prominently displayed by means of indicators. Quality production was rewarded in various ways by coupling production bonus with a factor which took quality into account. Quality ratings of employees counted very much in promotions and for special job selections.

Slogans Displayed at the Singer Plant

THINK About Quality	HIGH QUALITY Protects our reputation	STOP WASTE NOW!	Customers ROAR For QUALITY
Now More than Ever Quality Counts	Cut Waste Cut costs	Getting a Big Hand Quality	A little extra cost can wreck a job
Rework is waste	Quality depends on *you*	Are *You* Proud of *our* quality	A Quality product sells itself

A *Good* Quality
Better business
More Work.

4 : Inspection & Metrology

IN exercising the function of quality control inspection and testing play a fundamental role. They provide the basis for quality evaluation in various stages of manufacture (including acceptance of raw materials and other bought items), and through this evaluation adequate control procedures could be designed so that the specified 'quality' could be built into product and placed in the hands of the consumer.

The development of science and technology have been successful in providing consumers with better and consistent quality products. However, it should be emphasised that this development would not have been possible without development of better methods of measurement, and laying down product specifications. The progress in the science of measurement has always played a fundamental part in the practical applications of many researches in the fields of science and technology. This has found clear emphasis in the statement by Lord Kelvin, "that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be".

In all the countries visited abroad the progress of the development of inspection equipment for industrial uses has been adequate and satisfactory. Many inspection equipments for routine purposes have been developed for quick inspection, and with the object of reducing cost of inspection; automatic gauging and sorting procedures have been developed; process control instrumentation with feedback devices have been successfully implemented; installation of nondestructive testing programmes is on the increase. In most of the factories visited there were many instances where the company had developed its own inspection equipments for special situation either independently or in collaboration with others.

Significance of Inspection

In all the factories visited the team found that inspection was given an important place with a view to ensure that:

1. Materials used are as specified.
2. Processes of manufacture are carried in proper sequence and under controlled conditions.
3. Parts are free from corrosion, pitting, crack and other visible defects.
4. Parts conform to all the requirements of the specification in regard to accuracy, finish, strength and performance.

Duties of Inspector

The Inspector carries out the following duties:

1. Interpretation of specification.
2. Measurement of product.
3. Checking for conformance to specification required.
4. Disposition of product.
5. Maintenance of inspection records.

Depending on the type of the product, the methods of manufacture and the facilities available, the nature and amount of inspection were found to vary. Where to inspect, when to inspect and how much to inspect are usually determined by the Chief Inspector. Further comprehensive Inspection Manuals are issued for guidance of the inspectors. In some of the industries where safety and reliability are of primary importance, it was found that there was a greater amount of inspection (as in the case of an aircraft industry).

Systematic inspection ensures that (a) each operation has been carried out satisfactorily and in proper sequence, (b) no scrap is produced undetected, and (c) any undesirable situation is immediately reported to concerned authorities

for timely action. In general the following are the various types of inspection used by the industries.

1. Receiving Inspection
2. Manufacturing Inspection
   (a) View Room Inspection
   (b) Patrol Inspection
   (c) Process Inspection
3. Inspection during Assembly
4. Functional Testing

Receiving Inspection

In almost all plants visited incoming materials are being inspected prior to taking them into stock. Incoming inspection is somewhat different from other types of inspection inasmuch as the main purpose of inspection at this stage is to sort out good materials from bad. Also no information regarding the quality level of the goods received is available. Usually sampling inspection based on Specification MIL-105B or Dodge Romig tables are employed for inspecting the incoming goods. The following system is used by Lock-heeds and Rolls-Royce.

All materials received are checked

(a) for requirements laid down in the purchase order/contract.

(b) for damage, corrosion, crack, etc., and evidence of prior inspection.

(c) for proper inspection documents like Airworthiness affidavit (USA) or Release Notes (UK).

(d) for tests reports in case of raw materials.

Further samples from raw materials are sent to laboratory for confirmatory check. Before stocking, raw materials are colour-coded and batch-numbered. Colour-coding helps the Stores department to identify the material specification at the time of issue. Batch-number is crossreferenced to the incoming inspection documents and helps to trace the complete history of a defective part. The batch number is marked on the inspection documents and the parts wherever possible.

Instruments and accessories are functionally checked before they are accepted into stores. Important units are picked up at random from the first 1 or 2 batches of supplies and stripped for a detailed examination. Any defects or deficiencies noticed will be reported to the vendor for corrective action.

The receiving inspection unit is fully equipped so that a thorough inspection can be carried out at the time of receipt. Some of the facilities found were:

1. Go and no go gauges, plug, ring, etc.
2. Measuring instruments like calipers, micrometers, dial test indicators.
3. Non-destructive testing equipments like Ultrasonic flaw detector, magnaflux crack detector, etc.
4. Test benches to check hydraulic and electrical, oxygen and other types of accessories.

Great importance is attached to inspection of raw materials as the quality of final product is dependent on the quality of raw material, in regard to accuracy and finish, strength and chemical composition, etc.

Suspect materials are kept in a quarantine pending further investigation. Many firms accept materials on the basis of certification from a vendor who has proved to be reliable in the past. All rejections are reported to the purchase department so that they may know the quality level of the various vendors supplying materials.

Manufacturing Inspection

Inspection during manufacture differs from receiving inspection due to the following reasons:

1. The manufacturing process can be watched and controlled.
2. All data pertaining to raw materials and processes are available.
3. Acceptance and defect prevention functions are equally important.
4. There is little time lag between detecting the defect and notifying all concerned for necessary action.

(a) *View Room Inspection*: Booths or cages are built at convenient areas on the shop-floor and the parts produced in the shop are sent to the inspectors stationed at these booths. This arrangement offers the following advantages:

(i) the inspectors are able to inspect parts carefully and without interference from outside:

(ii) inspection gauges, blue prints and other technical data required for inspection can be kept on hand;

(iii) there is no danger of the unserviceable parts getting mixed up with good parts.

(iv) supervision of inspection is greatly facilitated since all inspectors are working in one enclosed area; and

(v) inspection records can be prepared expeditiously and passed on to the concerned people for necessary action.

The disadvantages of this type of inspection are:

(i) longer inspection cycle.

(ii) extra movement of parts for inspection. This will be particularly difficult for unwieldy parts.

(b) *Patrol Inspection*: In this arrangement the inspector carries out inspection at site. The advantages are:—

(i) Saving time and labour involved in transporting the material particularly heavy ones from place to place.

(ii) Chances of damage due to handling are reduced.

(iii) Inspectors placed at various stages in the production are able to isolate defective work then and there.

(iv) It is possible to reduce the amount of inspection in the View Room if a thorough patrol inspection is carried out.

(v) Since patrol inspection is in phase with the work as it grows from raw material to final product, a systematic check can be ensured. Patrol inspection is also useful for carrying out periodic checks on machine setups and also to watch whether the operator is using proper techniques and tools during production.

(c) *Process Inspection* (*processes like heat-treatment, plating, etc.*) : The quality of a process like heat-treatment is mainly dependent upon proper control that is exercised. Often automatic controls are provided to keep the temperature within specified limits. The inspector keeps a close watch on the various control points which affect the process and notes the temperatures, time of soaking etc., structurally important parts are heat-treated along with test pieces. If the test pieces fail in laboratory tests the entire lot of parts which it represents may have to be rejected. Test pieces and parts are given heat number for easy identification.

Rolls-Roye Co., UK, uses a heat-treat card for controlling the heat-treatment of structurally important parts. This card contains all details of heat-treatment processes like the temperature, soaking period, quenching medium composition of the material, strength required, etc. This card is signed by the inspector and forms a permanent record of inspection.

Plating baths are checked by taking out samples of electrolyte at predetermined intervals and sending them for chemical analysis. The batch is corrected based on the results of laboratory check. The plating efficiency is checked by plating a standard specimen along with the parts and assessing the thickness of metal deposited on it.

Inspection during Assembly

Inspection during this stage is characterised by the fact that it mainly consists of acceptance or rejection of the completed assembly and ensures that:

(a) The assembly stage is complete in all respects.

(b) Detail parts have undergone all previous operations and bear evidence of prior inspection.

(c) The parts are serviceable and free from damage, corrosion, deterioration, etc.

(d) Proper tools and jigs are being employed during assembly.

(e) Proper sequence of assembly has been employed.

(f) All pre-treatments and protective finishes have been given at appropriate stages.

(g) Proper assembly techniques have been employed.

(h) The assembly is fully interchangeable and accurate within the limits laid down.

(i) The assembly is free from distortion or undue strain.

Since inspection of final assembly is the last check-post in the manufacturing cycle, generally 100% inspection is carried out at this stage.

In some cases where safety is of prime importance, as for instance on the flight controls of an aircraft, two or three independent checks will be carried out.

In Toshiba, Japan, the transistor receiving sets are 100% checked for performance and minor faults are rectified before units are certified for release.

Functional Testing

Each unit is functionally tested to ensure that it meets with all the requirements laid down in the relevant specification. This inspection is very important as the customer satisfaction and reputation of the firm depend on the satisfactory performance of the units. Each unit is tested under rigorous conditions so that it can be safely expected to give trouble-free service for a considerable time. In Rolls-Royce each and every aero-engine and accessory is given an endurance run after assembly for specified periods under different conditions.

In Lockheeds every aircraft is given comprehensive air-test by a qualified pilot and only after it passes all these tests, the aircraft will be certified by FAA as airworthy.

Tool Control & Metrology

Measuring tools are as important to the inspector as the production tools are to the workman. Hence control and maintenance of measuring equipments have been given a very important place in engineering industry. In many plants visited, we found that the tool and gauge control was exercised by the inspection department. Separate sets of gauges were issued to the shops and inspection. The shop gauges and inspection gauges were found to be of the same accuracy thereby ensuring that parts passed through shop gauge will also pass through inspection gauge. Master gauges are used for calibration of shops and inspection gauges and are not issued to Shop under any circumstance.

Measuring Equipments

The following are the different types of measuring tools and equipments used by the inspection:

1. Limit gauges
2. Measuring Instruments
3. Automatic gauging equipment
4. Non-destructive testing
   (a) X-ray
   (b) Magniflux
   (c) Ultrasonic
5. Visual Standards
6. Test equipments.

Limit Gauges : These are used for "Inspection by Attributes, i.e., for sorting good and bad parts. Limit gauge is cheap, simple and quick and can be used even by a semi-skilled operator. As it does not give the exact amount of variation it cannot be employed when it would be required to know the exact amount of error.

Measuring Instruments: The most commonly used measuring instruments are micrometers, vernier calipers, dial indicators, vernier protractors, etc. These are used when it is necessary to measure the exact dimension.

The dial test indicators are very useful for quick check. They can also be used as snap gauges by fixing them in suitable adaptors and set-ups.

The following special types of measuring equipments are used in many firms.

(a) *Air gauges* : Used for measuring the dimensions of a bore or hole to close accuracies. Since there are no moving parts and the gauging head can be adopted to measure relatively inaccessible dimensions, it is very simple and economical in the long run. It has the advantage over solid plug or ring gauges in that, the exact dimensions can be obtained. It can be used by the operator to check the job on the spot for ovality, out of parellis etc. Since the mandrel of the gauge is always kept below the nominal size to be measured there is not much wear in it.

(b) *Optical measuring equipment* : Examples are the tool maker's microscope, projection comparators, optical flats and TALYSURF. Tool Maker's microscope is used for checking irregular profiles, accurate locations of holes, angles, etc. Since the image of the object is magnified, even small discrepancies are shown out clearly. In gear inspection projection comparators are widely used. In this type of instrument the object being checked is illuminated so that a magnified shadow of its contour is cast on the

screen for detailed examination or for comparison with a reference standard of known accuracy.

(c) *Optical flat and TALYURF* : Used for checking the accuracy of a ground or lapped surface.

Automatic Gauging Equipment: This system is extensively used in a mass production industry where the number of parts is large. It is also useful when automatic control has to be exercised during process of manufacture and also when it would be necessary to check a number of dimensions in relation to one another accurately. In Nakayo Communication Manufacturing Co., Japan automatic gauging was employed to segregate the parts into three different sizes as they came out of production line.

Non-Destructive Testing: The testing methods for detecting flaws and defects in materials without impairing the usefulness or serviceability of the material is termed as non-destructive testing (NDT). The increased demand on product reliability especially the critical requirements in the fields of aircraft, missiles, nuclear energy and electronic components have been responsible for the rapid growth of non-destructive methods of testing. The test methods utilised are visual, pressure and leak, penetrant, thermal, radiography, acoustic (sonic and ultrasonic), magnetic, electrical and electrostatic, electromagnetic induction and others. The Team members saw NDT departments in Lockheed California Co., USA, the Hirsch Research Centre (GEC), UK, and Rolls-Royce Ltd., UK. A brief description of some of these NDT methods may be found in the following sections. Figures 12-41 supplement the discussion (based on the paper: Non-destructive Testing by W. G. Cook, Rolls-Royce, Ltd., UK; Figures 1-30 are taken from this paper. See also Non-destructive Testing, W. J. McGonnagle; McGraw-Hill Book Co., 1961).

Visual Testing: Visual method is the oldest and simplest of methods of NDT. Of course visual inspection is also an integral part in other methods of NDT. In this method the test piece is illuminated with light and examined with the eye, sometimes with magnifying glasses. It should be emphasised that high magnification may not always be necessary or desirable. High power magnification are intended for looking in detail at something already found. Visual methods of inspection always require skill and experience.

Pressure and Leak Testing: In this type of testing the flow of air, gas or liquids through the defects reveals the presence. The pressure within the hollow test object is made grater than the outside pressure; a simple example would be testing of automobile tubes and leaks are detected when inflected tube is immersed in water.

Penetrants: Liquid penetrant inspection may be thought of as an extension of visual inspection methods. The difference is that the liquid penetrant methods provide a contrast between the defect and the background and makes detection fairly easy. In this method of inspection, only surface defects or defects which are open to the surface are revealed (see Figures 12-16). The following defects could be detected provided they are open to surface, and act as capilaries to drawing the penetrant: grinding cracks, welding cracks, casting cracks, fatigue cracks, shrinkage, blowholes, seams, laps, pores, coldshuts, porosity, lack of bonding, pinholes in welds, through cracks, forging laps and bursts, gauges, tool marks and die marks.

The technique used in penetrant inspection is that the clean component is covered with the penetrant and time allowed for liquid to enter the crack. The surplus is then removed from the surface and the penetrant drawn out by application of a fine film of inert white powder. The colour of the penetrant shows up against the background and the natural seepage from the crack gives a larger area of signal than the original crack. Penetrant techniques are applicable to all metals as well as to glazed ceramics, plastics and other non-porous materials. A special penetrant is used for locating flaws on a porous surface such as unfired ceramic materials. The method is applicable to either magnetic or non-magnetic materials where magnetic particle inspection cannot be used.

Thermal Methods: The method consists in applying heat (direct, electric, induction, infrared) to the test specimen and observing the temperature distribution. Flaws alter this distribution which can be detected by the use of temperature indicative substances, wax, temperature sensitive phospors, infrared film, thermocouples. Non-conducting areas (poor bonding) are outlined. The method could be used for checking brazed or bonded areas.

Magnetic Flaw Detection: This test is applied to magnetisable components and relies on the fact that the defects have a lower permeability than the material itself and consequently distort the magnetic field. At or near the surface this

distortion causes a leakage field which is strong enough to attract fine particles of magnetic material. The accumulation of particles indicates the defect which may be a crack, slag inclusion, segregation, or change of structure. Not all of these are necessarily causes for rejection (see Fig. 17). The magnetic powders in use are generally iron oxide suspended in a paraffin and black powder is the most common, although red, yellow, silver and fluorescent varieties are available. These variants are used in attempts to increase the contrast between the flaw indication and the background. Another way of doing this is to paint the background white or use thin, white adhesive tape. The tape technique shows very promising results for weld inspection and the results of tests compare very favourably with X-ray. Fig. 18 shows the procedure and Fig. 19 shows typical results.

Eddy current techniques can be used to inspect electrically conducting specimens for defects, irregularities in structure, and variations in composition. Applications of eddy current testing include metal sorting, detection of cracks, voids, and inclusions, measurement of plate or tubing thickness, determination of coating thickness, and measurement of thickness of non-conducting films on electrically conducting base material. Eddy current tests are most effective for locating irregularities near the surface of the specimen. When a coil carrying alternating current is brought near a metal specimen, eddy currents are induced in the metal by electomagnetic induction. The eddy currents induced in the metal set up a magnetic field which opposes the original magnetic field. The impedance of the exciting coil or any pick-up coil in the close proximity to the specimen is affected by the presence of the induced eddy currents. The path of the eddy currents is distorted by the presence of a defect or other homogeneties. The apparent impedance of the coil is changed by the presence of a defect. This change in impedance can be measured and used to give an indication of defects or differences in physical, chemical and matellurgical structure. (see Figures 20-22).

Ultrasonics: Vibrational waves which have a frequency above the hearing range of the normal ear (a frequency greater than 20,000 cps) are called ultrasonic waves. Certain phenomena which occur at ultrasonic frequencies are not usually observed in the audible range.

The principle of contact scanning is shown in Fig. 23 and Figs. 24 and 25 show applications of this simple principle. The extrusion defects found in the rectangular bar are shown in Fig. 26, the bar having 0.150″ machined off one edge to reveal the defects which are completely internal. Defects found in the round bar are shown up by penetrant in Fig. 27. Fig. 28 shows a fractured bar and Fig. 29 shows pipe located by ultrasonics. An alternative method of finding these defects by ultrasonics is shown in Fig. 30, using as angle probe and a beam of ultrasonic waves echoing up and down along the bar.

The principle of immersion scanning is basically the same but coupling between the transmitter and the component is effected by a layer of water instead of a film of oil. The basic idea is shown in Fig. 33 and a simple tank working on this principle is shown in Figs. 34 and 35. This technique ensures complete scanning of suitable areas and this can be made fully automatic with monitoring to indicate defects.

Typical defects located inside steel forgings are shown in Figs. 36 to 39. The ability to assess the depth of these flaws as well as their radius enabled predictions to be made as to whether they would fall across or in the finished section. Only in this case can the forging be rejected since defects outside the finished section will machine away without being noticed.

Under suitable conditions ultrasonic waves can be generated which skim the surface of the component and defect cracks by echo. Echoes are also produced by sharp corners and radii so the possible applications are limited. Fig. 40 shows a surface wave crystal in use.

The transmission technique consists of sending a continuous beam of sound through a component, with internal reflections if necessary, and measuring the intensity of the emergent sound beam. The presence of a defect causes a sharp fall in intensity. Fig. 41 shows an instrument working on this principle.

Radiography: The use of X-ray or gamma radiation is termed as Radiography. The intensity of the penetrating radiation is modified by passage through material and by defects in the material. The phenomenon of differential absorption is the basis of radiography. The contrast (different in density) on the developed film between the image of an area containing a defect and the image of a defect-free area of the specimen permits the observer to distinguish the flaw.

Special Studies and Research: Fibre

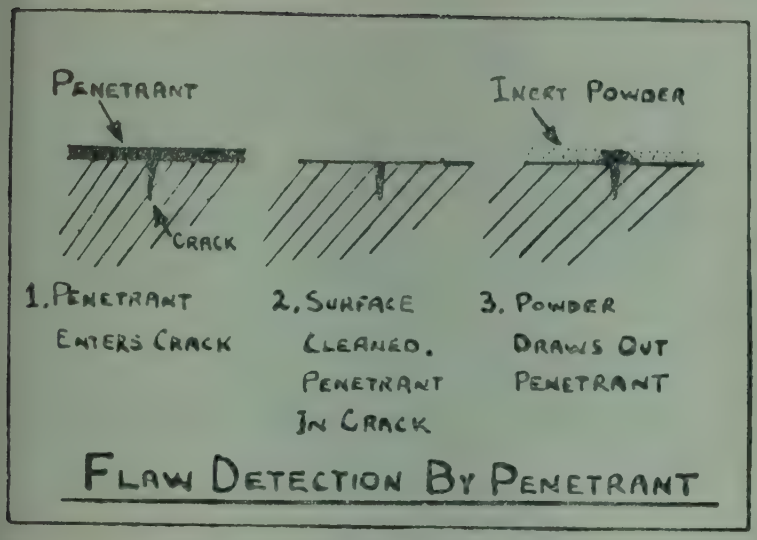

Fig. 12—Principles of Penetrants

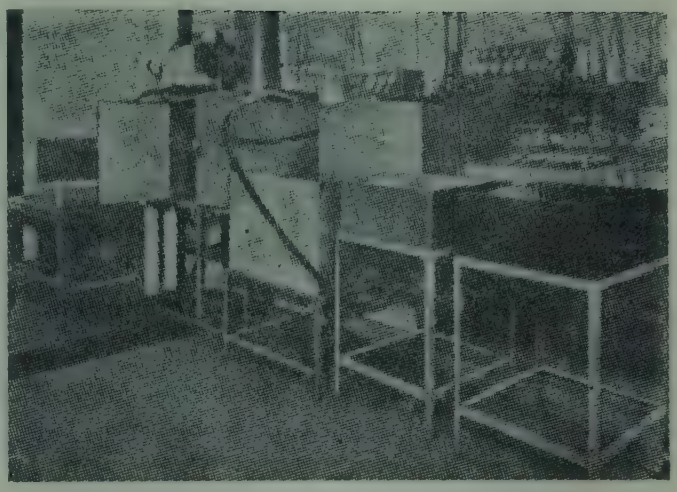

Fig. 13—Pilot Plant for Penetrants

Fig. 14—Washing under Black Light

Fig. 15—Developing

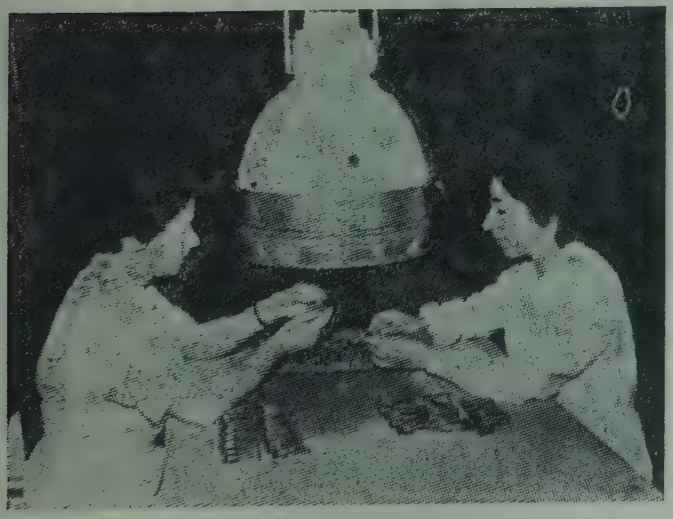

Fig. 16—Inspecting under Black Light

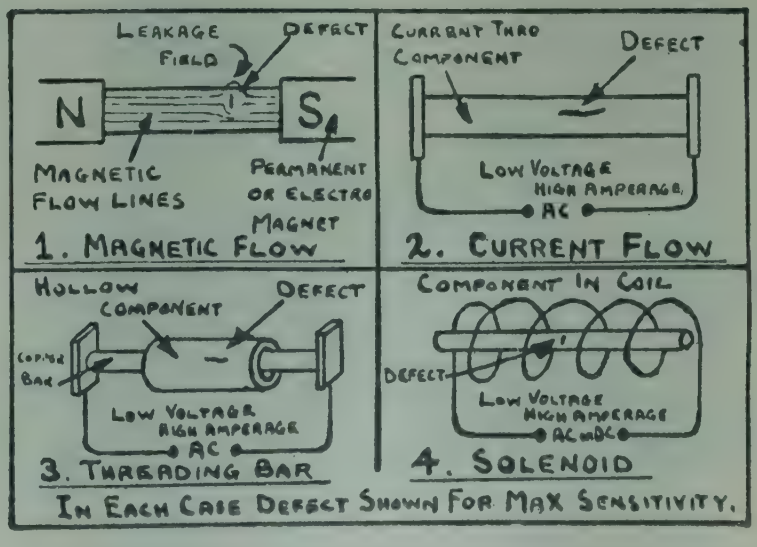

Fig. 17—Principles of Magnetic Flaw Detection

Fig. 18--Magnetic Weld Inspection

Fig. 19—Comparison of Magnetic and X-ray Results on Butt Welds

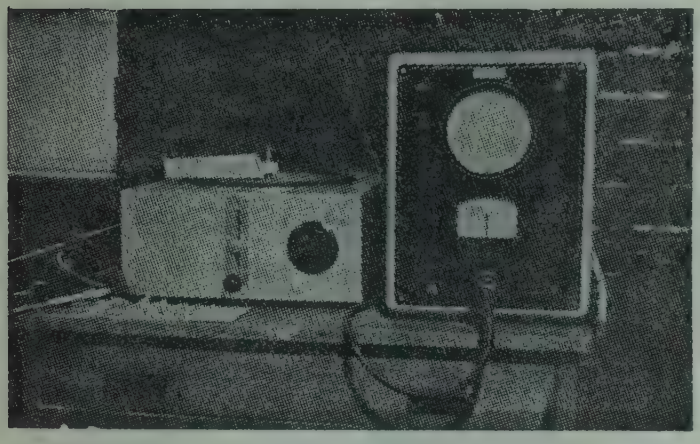

Fig. 20—Crack Detector for Light Alloy Compressor Blades

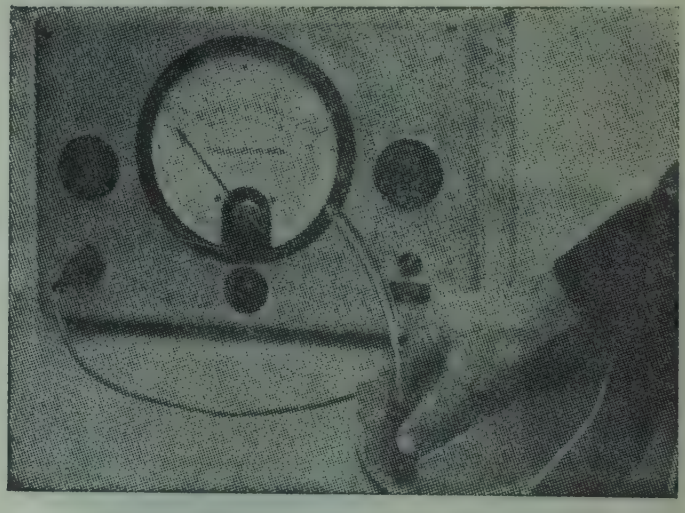

Fig. 21—Measurement of Anodic Films

Fig. 22—Sorting Materials by Eddy Currents

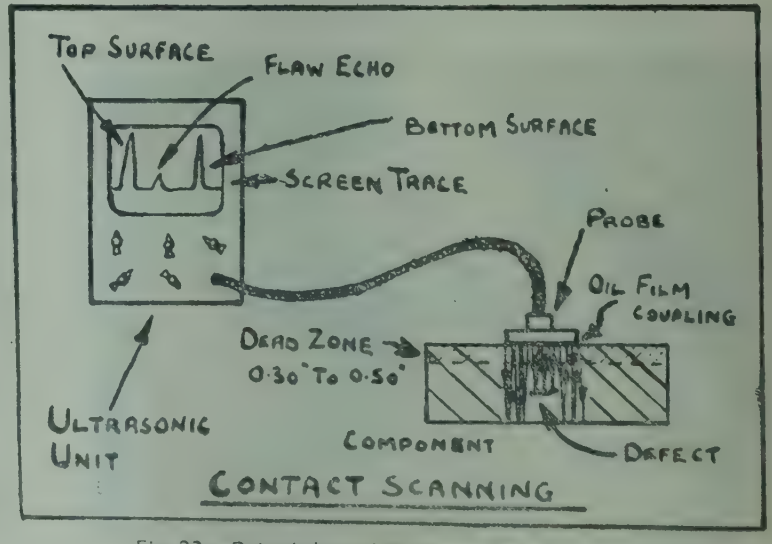

Fig 23—Principles of Contact Scanning

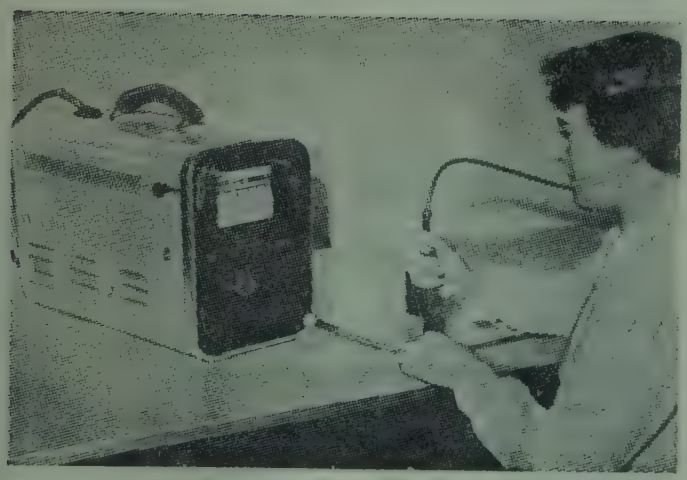

Fig. 24—Ultrasonic Inspection of Rectangular Bar

Fig. 25—Ultrasonic Inspection of Round Bar

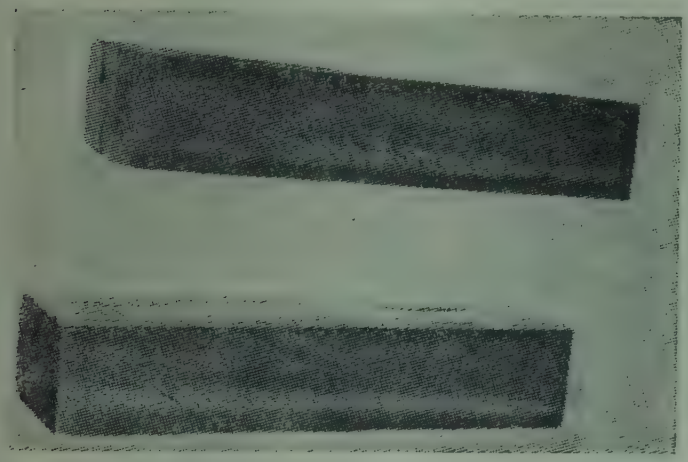

Fig. 26—Internal Defects found by Ultrasonics in Rectangular Bar (x 2/3)

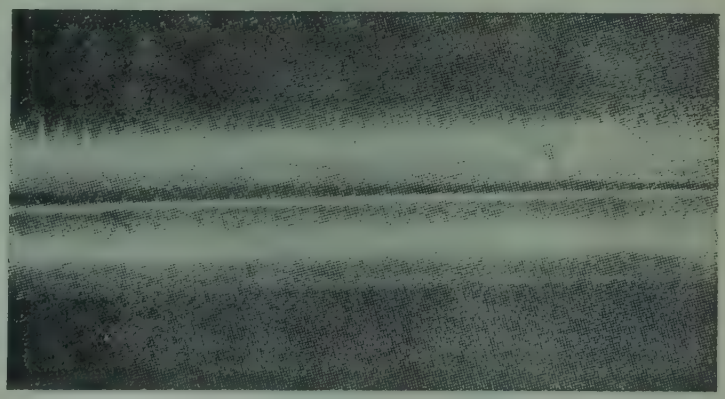

Fig. 27—Cracks in Round Bar found by Ultrasonic and shown by Penetrant

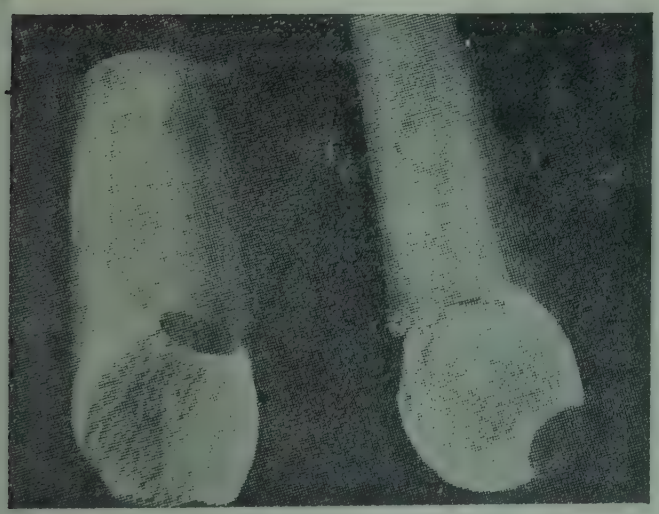

Fig. 28—Fracture of Round Bar showing Defect (x 1)

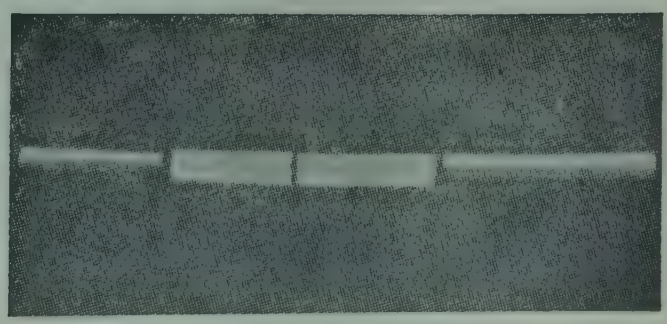

Fig. 29—Internal Pipe found by Ultrasonics (x $\frac{1}{4}$)

Fig. 30—Ultrasonic Inspection of Bar by Angel Probe

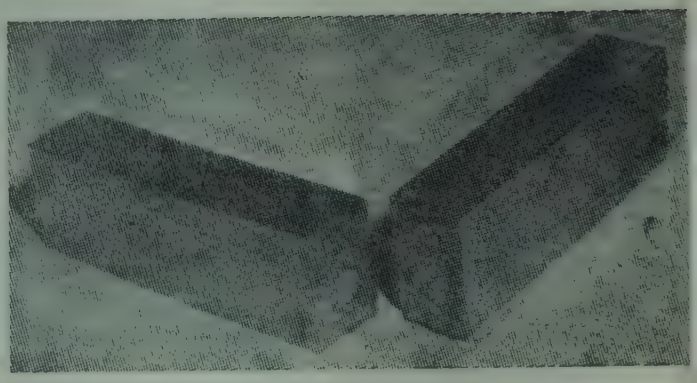

Fig. 31—Axial Flake in S 82 Steel found by Ultrasonic (x$\frac{1}{3}$)

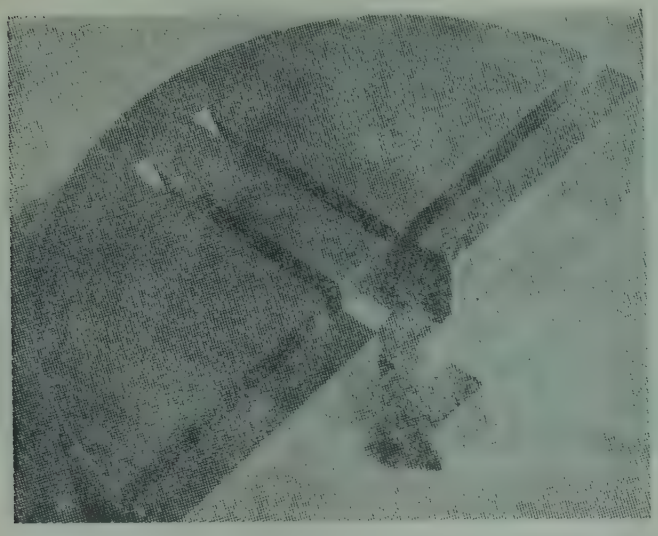

Fig. 32—Transverse Flake in Steel found by Ultrasonics (x $\frac{1}{2}$)

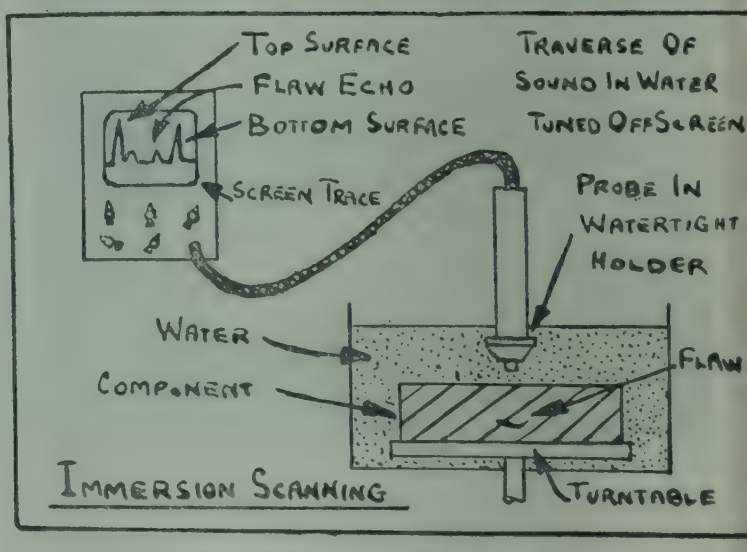

Fig. 33—Principles Immersion Testing

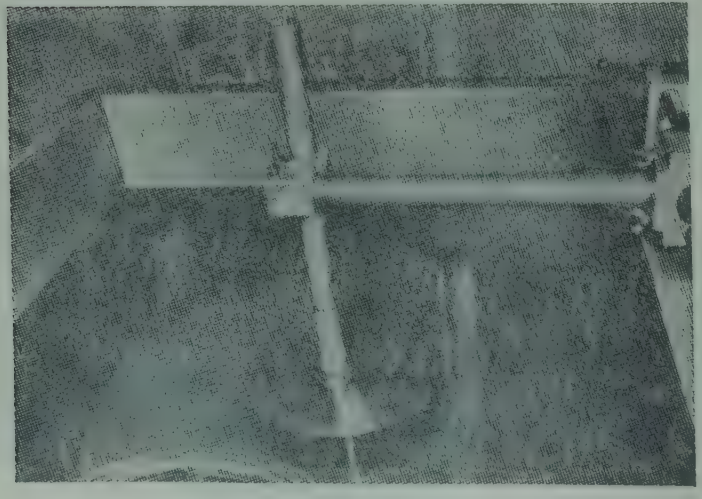

Fig. 34—Ultrasonic Immersion Tank

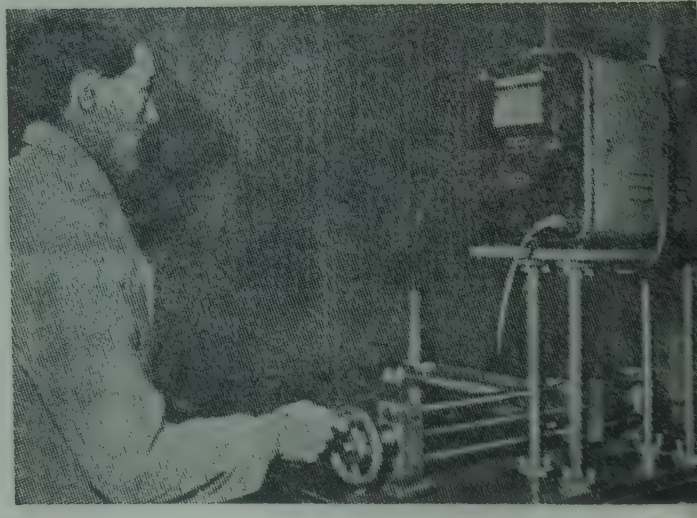

Fig. 35—Ultrasonic Immersion Tank in Use

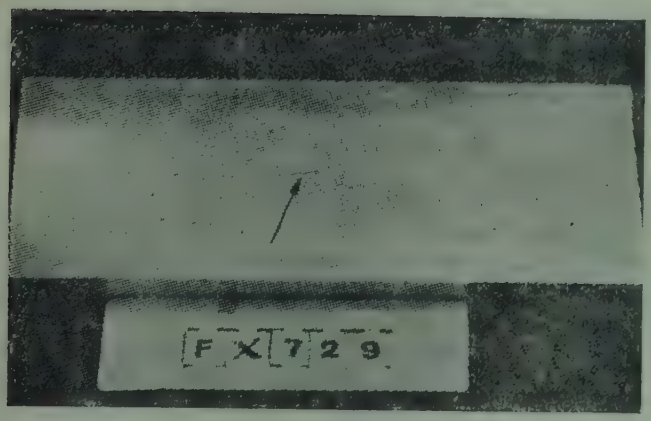

Fig. 36—Defect found by Immersion Testing (x ½)

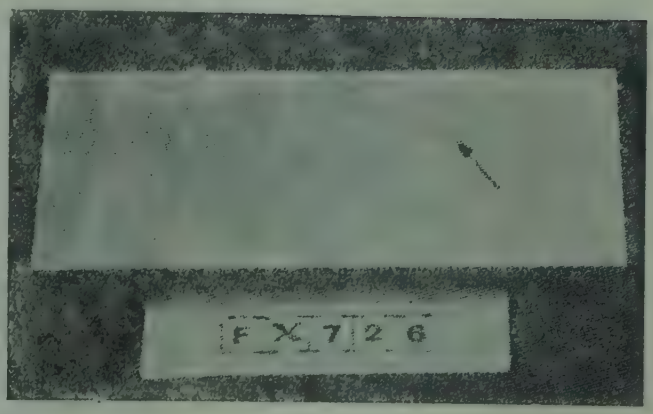

Fig. 37—Defects found by Immersion Scanning (x ½)

Fig. 38—Disc Cut and Fractured to show Defect (x ½)

Fig. 39—Defects in Forging found by Immersion Testing (x ⅓)

Fig. 40—Inspection by Ultrasonic Surface Waves

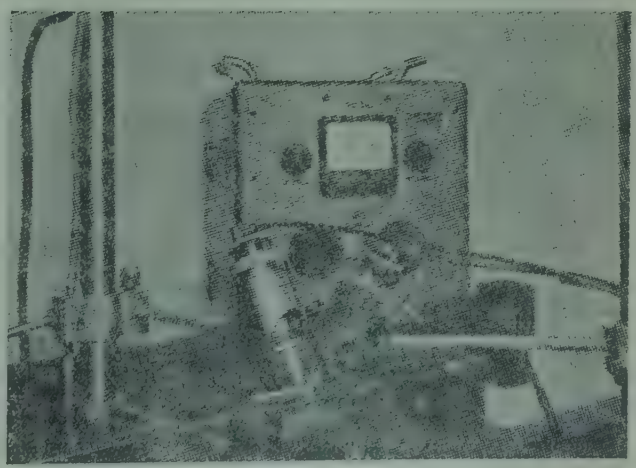

Fig. 41—Inspection by Ultrasonic Transmission

Optics, which will be of great help in industrial inspection, have been developed by Bausch and Lomb Inc., USA. This is based on the principle that light can be transmitted by total internal reflection from one end to the other of a long thin glass fibre regardless of the convolutions of the fibre. Further, if fibres are properly stacked and orientation maintained between each end of the stack or bundle, each end forms an optical plane and an image can be transmitted from one end to the other. To eliminate leakage or 'cross-leak' between fibres, each fibre is insulated by coating it with glass of a lower index than that of the core (see Figure 42). The bundle in Figure 42, is 39" long and

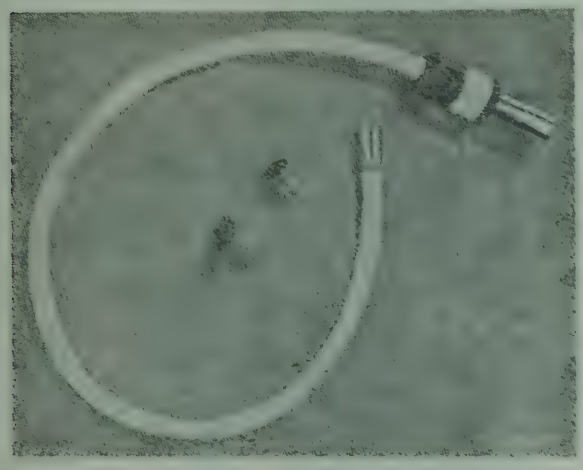

Fig. 42—Coated A Fiber Bundle

has a $\frac{3}{16}$" x $\frac{3}{16}$" display on each end. It is made of coated fibre 15 microns in diameter and is encased in an articulated rubber casing for maximum protection and flexibility. Each end is threaded and shown with an eyepiece on one end and a choice of three collective lenses.

In USA, deep concern has been felt about the lagging behind of metrology. Therefore, as a long range policy a centre for Measurement Science has been started as a combined venture between Government, the Industry and George Washington University, Washington D.C. This Centre has been able to get the youth of America interested in Metrology and to provide them with specialised education to pursue it as a career and is operated by the University's School of Engineering. It was established in September, 1960, with the collaboration of the National Bureau of Standards, and a financial boost from the Martin Company, Baltimore, Md., which has been the prime industry spark plug behind this idea. A group, comprising those interested in furthering the Measurement Science, has agreed to support the Centre by contributions of $5,000 minimum annually. Three valuable accomplishments are realised from the generosity of the Associates of the Centre for Measurement Science as they are known: "The Research Programme includes research and development work related to measurements undertaken as independent studies by staff members of the Centre or by personnel of Associates; the Service Programme provides consultation and assistance of faculty, staff and facilities of the Centre on specific problems in measurement; and the Education Programme which offers a course leading to an Engineering Technologist Certificate and the degree of Bachelor of Science in Engineering as well as Master and Doctor of Science degrees." (*Industrial Quality Control*, December, 1961).

A special feature noted in Rolls-Royce Ltd., UK, was the Quality Rig testing, simulating service conditions. According to the company's experience this has helped in establishment of safe minimum acceptable standards. These tests reveal how 'bad' components affect quality and serviceability and in some cases have led to relaxation in standards. Since in any field of endeavour the economics desire to use all the material available is in conflict with the requirements of the minimum standard of quality, such test can be of great value by reducing the amount of scrap or by allowing an inferior and cheaper grade of material to be used satisfactorily.

Rolls-Royce Ltd., UK have sponsored many research projects for replacing destructive tests with non-destructive testing methods; some of them are tensile strength, creep properties of metals, welding.

Visual Standard: Of all the types of inspection, visual inspection of a defect is the most difficult one since acceptance or rejection depends on the personal judgment which varies from inspector to inspector and in the same inspector at different times. Further, it would not be possible to measure certain types of visual defects. In such cases, visual standards are made use of. M/s. Bausch and Lomb have developed a visual standard for cosmetic defects like digs and scratches. Digs and scratches of varying sizes are made on a piece of glass and graded from 1 to 8, No. 1 being smallest size of defect and No. 8 being the biggest size. What grade of defect is acceptable or not depends on the purpose for which the lens is used. The process sheet will indicate the grade of defect that is permitted and the area where it can occur. The visual

standard is used by the inspector for comparison while checking the production lenses.

Visual standards are also widely used for comparing different shades in painted surfaces.

Test Equipments: These are used for functional testing of the finished product before it is certified as fit for shipment. Many of the firms design and build their own test equipments to suit their special requirements. Their equipments are calibrated at periodic intervals fixed by the Quality Control Department.

Control of tools, gauges, test equipments, sub-standards and reference standards: In order that parts produced are of consistent and of acceptable quality, it is necessary to keep the production tools and checking gauges and test equipments always accurate. No tool can produce a job more accurate than its own inherent accuracy. Also no gauge can measure an article more accurately than its own inherent accuracy. Hence systematic maintenance and control of gauges and test equipments is an essential requisite for maintaining the quality level.

A planned system of tool control aims at planned maintenance of all gauges and test equipments to a desired accuracy and periodic withdrawal for readjusting or reconditioning and checking with a sub-standard of known accuracy. One progressive engineering industry, Massey Ferguson have adapted the following control procedure for checking gauges with very satisfactory results:

1. Check all gauges on receipt for initial accuracy in standards room.
2. Classify gauges with various categories depending on the frequency of checks.
3. Serially number and raise a control card for each gauge giving the following details:
   (i) Sl. No., Part No. and nomenclature of gauge.
   (ii) Description of use.
   (iii) Dimensions.
   (iv) Classification of gauge.
   (v) Location of use.
   (vi) Supplier and date of receipt.

After each re-check the actual size and condition of each gauge are recorded on the card. This information helps in establishing the frequency of re-checks and the rate of wear in relation to the material (hard or soft) on which it is used. When once sufficient data are built, it would be easy to classify similar types of gauges bought from time to time. Further gauges are colour coded to identify the month or year in which they are calibrated.

Calibration of Test Equipments: The instruments used on test equipments should be of known accuracy in order that the results obtained while functional checks are representatives. Depending on the type of instrument, the amount of use, and the accuracy required, the frequency of re-inspection/re-calibration is fixed.

Calibration of Sub-standards and Reference Standards: (i) *Sub-standards* are kept in the standards room and under no circumstance they are issued to the Shop. They are used for periodic calibration of gauges and measuring equipments used on shop-floor. (ii) *Reference Standards* are masters and are extremely accurate. In America the reference standards are held by the National Bureau of Standards and National Physical Laboratory in UK. Sub-standards are periodically taken to these institutions for calibration against the masters. The masters are such that they do not change their accuracies by any measurable amount for long periods of time. They are checked once in 20 years against the natural standards like wave-length of krypton etc.

Inspection Records

Specifications for material and in-processes and other technical data (drawings, blueprints, etc.) are documented and readily available in the concerned departments and for ready reference. This was also the case with reference to inspection and inspection procedures.

In Nakayo Communication Equipment Manufacturing Co., Japan (employing about 300 people), all the specifications and technical data are micro-filmed and kept in the safe deposit vaults in the bank. This is to ensure the availability of design data, in case the factory records are destroyed by fire or other causes.

Maintenance

A good system of maintenance of gauges and inspection and test equipments were noted in most of the factories visited abroad. Some of the schemes are described in the following section. The instrument calibration and measurement standards of the Lockheed-California Co., USA, is described below in their own words:

Policy—It is the policy of the Lockheed-California Company to operate and maintain a secondary standards laboratory for calibrating all instruments used throughout the company.

Procedure—Procedures used for calibration stem from several sources. The Navy SLIM (Standards Laboratory Instruments Manual) is used primarily, with manufacturing procedures and specifications as second source. If no procedures exist, they are established by our own laboratory and administrative service personnel.

Item Identification—Purchased Instruments and measuring devices are identified and inventoried, then calibrated prior to release for use. A recall schedule is also established for categories of instruments.

Calibration: This is accomplished by the use of Reference and Working standards. The Reference standards, which are our stop standards, are known as "Secondary" since they are calibrated against the primary standards by the National Bureau of Standards, the body maintaining the country's only primary standards in the field of measurement. Our reference standards, having been calibrated against the NBS primary standards, are then used to calibrate our Working standards. The Working standards are then used to calibrate laboratory and test equipment throughout the organization.

Documented Calibration Results: Calibration results are documented on regular forms so that a record is kept of all calibrations and repairs by item identification.

Calibration Record Decals: Calibration record decals are also attached to each instrument, showing date of calibration, recalibration, due date, and the technician's initials.

Continuous Monitoring by Q. A. & Withhold Equipment Requiring Calibration: The use of all instruments is monitored by Q.A. inspectors to make sure that no instruments are in use beyond their recall date. Any instruments in any area, in use or not, with an outdated decal are withheld from use and returned for recalibration.

Our main calibration and measurement standards laboratory is located at Burbank, with a smaller laboratory at Palmdale for the calibration of equipment at the flight test base.

Within a couple of weeks, our new "Mobile Calibration Van" will be in operation. This unit consists of a specially air-conditioned 40-foot trailer van equipped for "on-the-spot" calibration of equipment at various plant locations, as well as remote test sites.

The inspection cycle for controlling gauges in the Singer Manufacturing Co., USA, is as follows:

Inspection Cycle for Controlling Gauges

Type Gauge	*Gauge Tolerance*	*Use*	*Inspection Cycle*
Snap	Less than .0010	100% Inspection (Machine operator or screener)	Daily
Snap	Less than .0010	Sampling Inspection	3 days
Snap	.0010 or more	Machine operator	6 days
Snap	.0010 or more	Sampling Inspection	6 days
Plug	Less than .0010	100% Inspection (Machine operator or screener)	6 days
Plug	.0010 or more	Machine operator	15 days
Plug	.0010 or more	Sampling Inspection	15 days
Thread	All gauges	All Inspection	15 days
Block	.0004 or less	All Inspection	15 days
Block	.0005 or more (Steel)	All Inspection	15 days
Block	.0005 or more (Carbide)	All Inspection	30 days
Ring	All gauges	All Inspection	6 days
Location	All gauges	All Inspection	30 days
Receiving	All gauges	All Inspection	30 days
Squareness	All gauges	All Inspection	30 days
Profile	All gauges	All Inspection	30 days

NOTE: When the inspection gauges listed on the thirty-day cycle, review gauge record cards, and send to Department 19 any gauge that has been active for a period of twelve months and has not been inspected by the gauge department in this period.

THREAD GAUGES

USE TOLERANCES ON THREAD CHART S—1068

GO SIDE MUST BE ON SIZE ON PLUS BUT *NEVER MINUS* ON PITCH DIAMETER

NO GO SIDE MUST BE MINUS AND *NEVER PLUS* ON PITCH DIAMETER

PITCH DIAMETER + CONSTANT = OVER WIRE SIZE

EXAMPLE: — FOR 60 THREADS
THREAD GAUGE — 3/16×28
WIRE SIZE — .02062
CONSTANT — .03093

PITCH DIAMETER—GO .1619	NO GO .165
.1619 P. D.	.165 P.D.
.03093 + constant	.03093 + constant
.19283 OVER WIRE	.19593 OVER WIRE
TOLERANCE GO SIDE	.1619 — .1622
NO GO SIDE	.1647 — .165

CHECK CLASS FIT

SINGER STANDARD SS2 IS PRIMARILY USED

GAUGE CONTROL PROCEDURE OUTLINE

The gauge control procedure outline in the Rolls-Royce Co., UK, is described below :

Check new gauges on receipt.

Classify gauges into categories for frequency of re-check.

Mark each gauge with a Serial No. and symbol to indicate frequency of re-check.

Enter details of each gauge on master chart.

Raise a History Card for each gauge.

Operate a system of withdrawing gauges from the shop-floor when due for re-check, and subsequently distributing them after check.

Operate a system for re-conditioning worn for damaged gauges.

REMARKS ON PROCEDURE: To deal with the procedure in rather more detail, all new gauges whether manufactured in our own Tool Room or purchased from Outside Suppliers, are, on receipt, initially checked in the Standards Room. (Metrology Department).

They are then, according to Type and dimensional tolerance, graded into categories for frequency of re-check, allocated a Serial No. and the details entered on the Master Chart.

A History Card is also raised for each gauge on which the following details are entered:—

(i) The Gauge Part No.
(ii) The Gauge Serial No.
(iii) Descriptions.
(iv) Dimensions.
(v) Name and Address of Vendor.
(vi) Classification Category.

When the gauge is ultimately issued for use in the Factory, the History Card is endorsed with details of its location in the Factory and the component on which it is used.

After each re-check the actual size and condition of the gauge is recorded on the Card.

This information is necessary in order to establish the frequency of check, adjustment, or replacement needed to ensure consistent accuracy of a gauge in relation to its Machine Shop usage, e.g.

A gauge could be issued to an Operator where it would be required for a 100% check involving possibly 400 applications of the gauge per day, whereas, an exactly similar gauge could be issued to an Inspector for a 10% Quality Audit check involving only 40 applications per day.

Also the amount of wear of the gauge depends on the type of material which is gauged: whether it is in the soft or finally hardened state, and also on the quality of surface finish to which the gauge is applied.

As the initial classification is based purely on the dimensional tolerance and nature of the gauge, it may, therefore be necessary to place the gauge into a different category and revise the frequency of re-check when experience has been gained of its usage and performance in the machine shops: and provision is made on the Master Chart for this.

Subsequent gauges, allocated to specific operations, are then classified in relation to the performance of previous gauges, on which information has been collated, by reference to the History Cards.

To ensure that the Gauges are checked at the Specified intervals, a Daily Gauge Inspection List is compiled in conjunction with a Rota and Work Load Chart, the Daily List being prepared on Masters from which duplicates are printed, and which are used each time the Rota cycle recurs.

A Gauge 'Tracker' (Messenger) is employed to operate a system of distribution and collection of the Gauges which is operated as follows:

Each morning the 'Gauge Tracker' takes the Daily Gauge List and withdraws from the stores the Gauges listed for re-call on that day.

The 'Tracker' then distributes the Gauges to the Inspection or Production Stations concerned and at the same time retrieves the equivalent gauges in current use.

The retrieved Gauges are then taken to the Gauge Control Room, checked by the Inspectors, and the findings recorded on the History Cards, the condition of the gauges is also endorsed on the Trackers copy of the Daily List as:—

(A) Satisfactory

(B) In need of reconditioning

(C) Scrap—To be replaced.

The 'Tracker' then returns the Gauges to Stores, together with the copy of the Daily List which now serves as a document of authority to the storekeeper to accept into stores for re-issue gauges classed as satisfactory, or to re-condition or replace damaged or faulty gauges as directed.

The charts and paperwork referred to in the previous remarks will require some clarification, as these are necessary to operate the outlined Gauge Control System.

The charts, etc. required are:—

(i) Classification Coding Chart

(ii) Master Chart

(iii) Daily List

(iv) History Card

(v) Rota and Work Load Chart.

Coding Chart—Code Key: A chart specifying the codes used to designate dimensional tolerances of gauges, and the classification of gauges for frequency of re-check. (Table 1).

Chart size—Foolscap.

Suitable as wall chart or for use in Folder.

Master Chart: A chart giving a complete list of gauges in numerical order and showing in code characters:— (Table 2).

(a) The type of gauge.

(b) The initial classification of the gauge.

(c) The day in the Rota calendar on which the gauge is due for re-check.

Chart size—Foolscap.

Each sheet, carrying a list of 30 gauges, is filed in a hard backed folder to form a comprehensive list of classified gauges in book form.

The Code Key, i.e., the Coding Chart, is pasted on the inner covers of the hard-back.

Daily Gauge Inspection List: A chart gives the following information:

(i) A list of gauges due for re-check on the day in the Rota calendar to which it refers.

(ii) Gauge No.

(iii) Stores Bin No.

(iv) Category of Gauges.

(v) Component Part No. on which gauge is used.

(vi) Inspection Station or Machine No. where the gauge is in use.

(vii) Date withdrawn from Stores.

(viii) Date returned to Stores.

(ix) Condition of returned Gauges.

The chart is designed for a dual purpose:

(A) To serve as a document for withdrawing from Stores, on a 'Loan' basis the Gauges listed on it; is retained by Stores until Gauges are returned to them and then suitably endorsed to that effect.

(B) To provide the following information to the gauge Trackers—The Inspection Sta-

TABLE—1

GAUGE CLASSIFICATION CODE CHART

CODE	TOLERANCE	FREQUENCY X = 1 DAY				
		CALIPER GAUGE Adjustable, Plain	PLATE GAUGE	PLUG GAUGE	CALIPER GAUGE Adjustable Screw Thread	PLUG GAUGE Screw Thread
A	0.0002	1X	3X	2X	1X	2X
	0.0015	3X	5X	5X	3X	5X
B	0.0015	3X	5X	5X	3X	5X
	0.003	5X	10X	8X	5X	7X
C	0.003	5X	10X	8X	5X	7X
	0.006	8X	15X	12X	10X	12X
D	0.006	8X	15X	12X	10X	12X
	0.020	20X	20X	20X	20X	20X

TABLE—2

MASTER CHART

*Sheet No.*_____

Type	Number	Class	Daily Sheet No.	Re-classification and Revision	Duplicate Sheet No.

tion or Machine to which each Gauge is to be delivered and from which the equivalent Gauge is to be withdrawn from use, for the purpose of re-checking.

Size—8″ x 5″

Suitable for filling in standard 8″ x 5″ filing cabinets or in Book Folder Form.

History Card: Designed to show the complete history of a Gauge—On initial inspection

of a new Gauge in the Standards Room a History Card is raised and endorsed with—

(i) The Gauge Part No.

(ii) The Gauge Serial No.

(iii) Description

(iv) Dimensions

(v) Name and Address of Vendor

(vi) Classification Category

When the Gauge is ultimately issued for use in the Factory the History Card travels to the Gauge Setting Room, where the Card is endorsed with details of the location of the Gauge in the Factory and the component on which it is used.

After each re-check the actual size and condition of the Gauge is recorded on the Card.

Size—8″ x 5″

For use in Standard 8″ x 5″ Filing Cabinets.

Rota and Work Load Chart: It shows total number of Gauges to be checked on each day in the Rota Calendar and the estimated time required for checking each Gauge.

Designed to ensure that an even 'spread' of work is allocated to the Gauge Checking Room over the whole Rota period.

Size—Foolscap—Squared Paper.

NBS of USA: The National Bureau of Standards (NBS) of the United States of America was established by Congress in 1901 to develop and maintain fundamental standards of physical measurement and to provide precise determinations of physical constants and the properties of matter and materials. The role of NBS in measurement standards and methods will be briefly discussed.

The Congress has assigned to NBS the following six functions:

(a) The custody and maintenance, and the development of national standards of measurement and methods for making measurements.

(b) The determination of physical constants and properties of materials that are of great importance to science and manufacturing.

(c) The development of testing methods for materials, mechanisms and structures.

(d) Cooperation with other governmental agencies and private organisations to establish standards practices, codes and specifications.

(e) Advice to government agencies on scientific and technical problems.

(f) Invention and development of devices for special government needs.

One of the most basic functions of NBS is relating to measurement standards and calibration services. As the custodian of the national standards of physical measurement, the Bureau is the ultimate source in America for the accuracy and reliability of the thousands of standards in common use. However, its responsibility for fundamental standards does not end with their custody and maintenance. It provides the necessary methods and instruments of measurement required to utilise these standards. Then, through calibration services, it ensures the accuracy of countless industrial and scientific instruments and working standards by comparing them with the master standards.

Today, tolerances for many items are expressed in hundredths, thousandths or even millionths of an inch and master standards must be very precise, since accuracy is lost at each stage of calibration. The accuracy of working standards, in turn, is vital to the mass production of interchangeable parts, to the development of new products and devices, to the commercial exchange of goods, and to the precise measurement of scientific quantities.

There are about 1000 different standards for measuring demensions, weight, force, energy, temperature, electricity, radiation, etc.

5 : Statistical Quality Control

STATISTICAL Quality Control (SQC) is considered as an integral part of the Quality Control programme in most of the factories visited in Japan, USA and UK. For instance, in the fundamental policy statement (quoted from literature supplied) of Tokyo Shibaura Electric Co., Ltd. (Toshiba), Japan, it is stated: "In production, the quality shall be controlled by taking up the more important characteristics, studying and analysing past production performance records and establishing control limits. Statistical methods of quality control shall be utilised to a full extent." This view is also expressed by Robert Schin of the Western Electric Company, "SQC is now an integrated and vital part of our engineering effort devoted to the maintenance of economic control and continuous refinement of our manufacturing process to consistently produce high quality products at the lowest possible cost." In most of the factories SQC techniques were utilised to the fullest advantage in the evaluation control and improvement of quality in various stages of manufacture.

Also in some of the factories SQC techniques were applied to non-manufacturing activities, e.g., research and development, design, maintenance, market research, anaysis of complaints, clinical applications, sickness, absenteeism, etc. In actual manufacturing the areas of applications were incoming material control, process control and product control. The most commonly employed techniques were control charts, sampling plans and simple experimental designs. Also techniques like Vendor Rating. Quality Index, Regression analysis, Demerit Rating plans were popular. In addition to these, the techniques of Evolutionary Operations (described in Appendix G) were applied successfully in Japan and USA specially to chemical processes.

Of course, there were a few factories in USA and UK where the application of SQC techniques were not in use appreciably. However, this may not be interpreted to mean that SQC principles were not in use at all. In fact, the basic principles of SQC, namely, planned collection and analysis of data, timely action, vendor assessment schemes and effective utilisation of data and graphical presentation were noted in these factories.

Incoming Material Control

The incoming material refers to the raw materials purchased from outsiders, and parts or assemblies bought from outside vendors. In all the factories visited in Japan, USA and UK there were good procedures to evaluate incoming quality and the disposition of the material. Some of the procedures are discussed below.

In Toshiba, Japan, vendor selection is done by sending two teams independently and rating the vendors. One team is a technical team consisting of persons from Quality Control, Engineering and Manufacturing. The other team is composed of persons from sales and purchasing. Each team is given a weight of 50% and at least 60 points have to be obtained for qualifying as a vendor to the company.

Mil-Std-105-A Sampling plans are used for acceptance of materials. Generally, Acceptance Quality Level (AQL) varies from 0.4% to 4%. The decision of acceptance or rejection is made by a committee.

The vendor classification of Toshiba is based on the following 7 items: (i) Amount of capital, (ii) Number of operatives, (iii) Number of engineers, (iv) Quality of equipment, (v) Application of Quality Control, (vi) Actual performance (percent rejection), and (vii) Technical ability.

The vendors are rated and divided into 4 groups.

The Lockheed Aircraft Corporation's (California Company) vendor acceptance scheme is explained in figures 43 and 44.

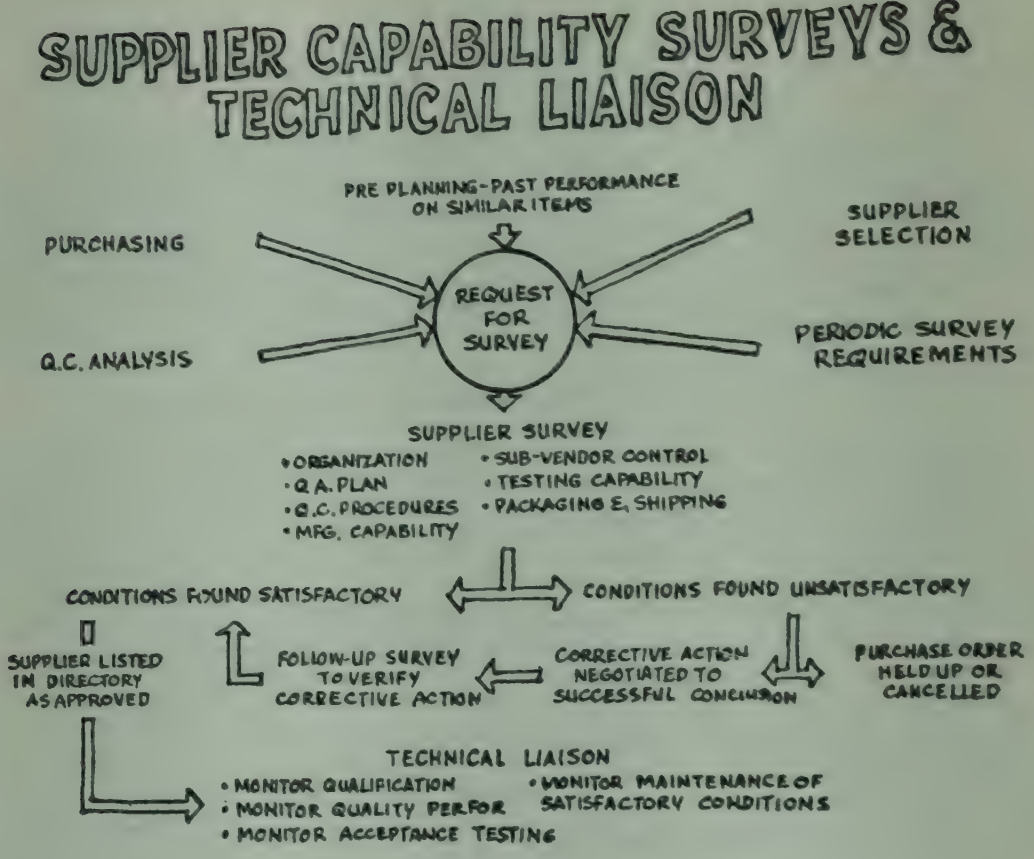

EXHIBIT A

SUBSIDIARY CONTROL

I REQUEST FOR SURVEY

II SURVEY REPORT

III APPROVAL STATUS

IV PERIODIC REVIEW

Fig. 43—Supplier Capability Surveys and Technical Liaison

SUPPLIER ACCEPTANCE TEST ANALYSIS & APPROVAL

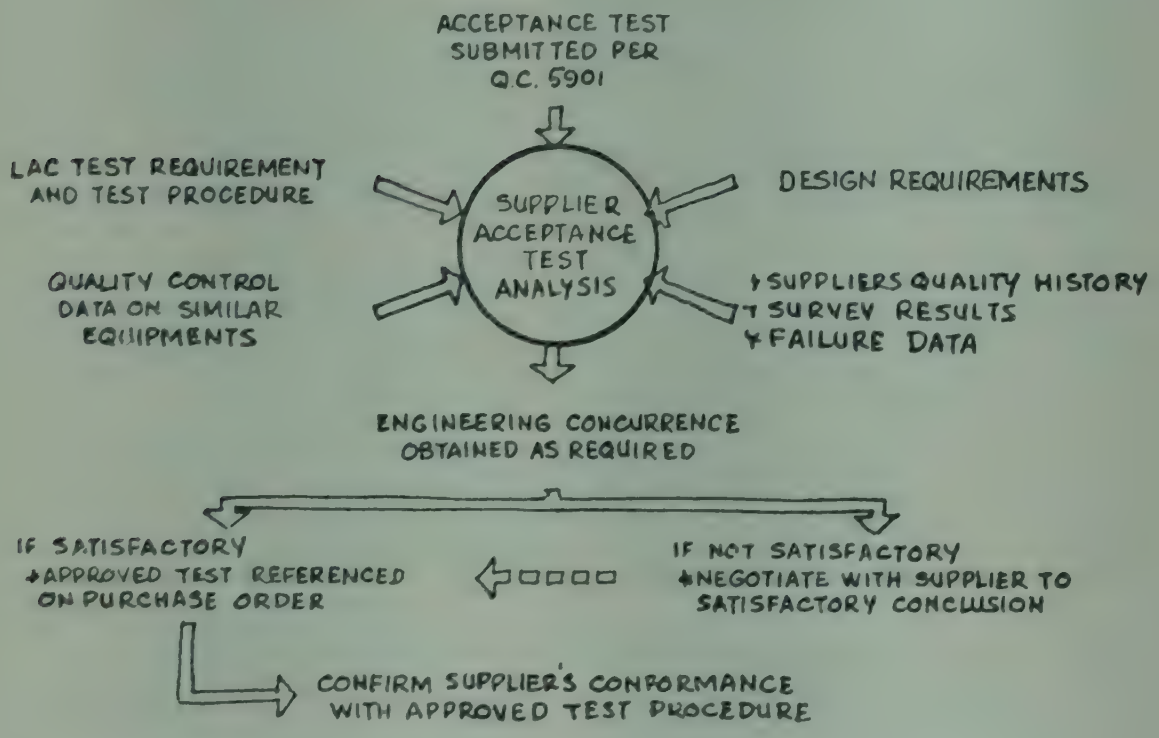
ACCEPTANCE TEST SUBMITTED PER Q.C. 5901
LAC TEST REQUIREMENT AND TEST PROCEDURE
DESIGN REQUIREMENTS
SUPPLIER ACCEPTANCE TEST ANALYSIS
QUALITY CONTROL DATA ON SIMILAR EQUIPMENTS
SUPPLIERS QUALITY HISTORY
SURVEY RESULTS
FAILURE DATA
ENGINEERING CONCURRENCE OBTAINED AS REQUIRED
IF SATISFACTORY
APPROVED TEST REFERENCED ON PURCHASE ORDER
IF NOT SATISFACTORY
NEGOTIATE WITH SUPPLIER TO SATISFACTORY CONCLUSION
CONFIRM SUPPLIER'S CONFORMANCE WITH APPROVED TEST PROCEDURE

EXHIBIT B

ACCEPTANCE TEST CONTROL

I QUALITY CONTROL PROCUREMENT POLICY

II FUNCTIONAL TEST CONTROL

III SUPPLIER TEST ANALYSIS

IV PURCHASE ORDER CONTROL

Fig. 44—Supplier Acceptance Test Analysis and Approval

Generally, hundred percent inspection is performed on all incoming materials at Lockheed.

The Vendor Quality Rating scheme of the Radio Corporation of America (RCA) is reproduced below:

"In order to characterize the Quality Performance of vendors in as concise and meaningful form as possible, a new Vendor Quality Rating (VQR) has been devised. This new rating utilizes the existing information regarding the number of lots submitted, and the percent of lots and total quantity accepted. These are now evaluated as an integral unit, as follows:

$$VQR = 100\ q.\ s.\ \sqrt{\frac{L}{L+1}}$$

where q = fraction of product accepted
s = fraction of lots accepted
L = number of lots submitted

"The resulting ratings will be numbered between zero and one hundred, with high values representing good performance.

Several examples may serve to clarify the new system.

Example 1 : Vendor *A* submits one perfect lot

$$q = 1.00,\ s = 1.00,\ L = 1$$

$$VQR = 100 \times 1.00 \times 1.00 \sqrt{1/2} = 70.7$$

Example 2 : Vendor *B* submits 10 lots; 9 are accepted; total fraction of product accepted is 85%

$$VQR = 100 \times .85 \times .90 \sqrt{\frac{10}{11}} = 72.8$$

Example 3 : Vendor *C* submits 15 lots; 8 are accepted; total fraction of product accepted is 60%

$$VQR = 100 \times .60 \times \tfrac{8}{15} \sqrt{\frac{15}{16}} = 31.0$$

"These examples clearly indicate that Vendor B is best, as we would expect, based upon his good performance over 10 lots. The perfect performance of Vendor A on a single lot is not conclusive enough to give him a superior rating. However, should such perfect performance be continued over several lots, a really high rating will result, thus confirming that he is truly a superior vendor."

Sonotone Corporation, Eastman Kodak Co., Ltd., Singer Manufacturing Co., and Bristol-Myers Ltd. (all of USA) use sampling plans for acceptance of incoming material. In Singer Manufacturing Co., single sampling plans are used up to lot size 500; for lot sizes greater than 500 multiple sampling plans are used. The sampling plans and necessary instructions are supplied. The statistical service section of the Eastman Kodak Co., and Bristol-Myers Co., provide the necessary sampling plans in their respective plants. In Bristol-Myers it was noticed that lot-plot technique was utilised in incoming material control for variable inspection.

The incoming material control scheme of Joseph Lucas Ltd., UK, is described below:

The scheme selected by Vendor Quality Department is that developed by Wharton of Philips Lamps Ltd., and known as the Philips Multiple Random Sampling Scheme. The operation is as follows:—

Take 5 samples of N units at random from the batch

(1) PASS batch if: - each sample contains less than P. rejects.

(2) REJECT batch if: (a) any sample contains more than P. rejects.

or (b) more than one sample contains P. rejects.

Take a second 5 samples of N units if:— just one sample contains as many as P. rejects, and then:—

(a) PASS batch if:—each of the second 5 samples contain less than P. rejects.

(b) REJECT batch if:—any of the second 5 samples contain P. or more rejects.

The Philips scheme provides a series of values of N and P for various ranges of batch size and control values. Our own application is standardised to utilise only the combination of N = 30, P=2 covering the range of batch sizes 2,000—15,000 units at what is termed "2% Control". The fact that the figures recommended by Philips are not used when the batch size differs from those within the standardised range will not materially affect the average quality protection, but is likely to cause rather more total inspection. It is felt that this disadvantage is more than offset by the simplicity in operation resulting from the standardisation of sample size and control limit.

Latterly, our application has been modified by the taking of three samples of 30 units instead of the five samples as laid down in the original scheme, and this, obviously, means some relaxation of control; the effect is shown in the comparative series of curves attached by which the characteristics of the scheme are defined (OC curves not included). In a few special instances, where there is a long history of satisfactory deliveries, one sample only of 20 units is taken, the batch being rejected if two or more defective units are found in the sample; or accepted if fewer than two are found. On the other hand, there are a limited number of instances where the normal control is not sufficiently critical, and where the full five samples of 30 units are taken with the control limit P = 1. This corresponds to the Philips "½% Control".

Operation of scheme: It is important that units comprising the sample are selected at random from all parts of the consignment; and if a batch is delivered in several containers, approximately equal numbers of units are taken from each—unless, of course, there are valid reasons for treating each container as a separate batch. The units are thoroughly mixed and then sub-divided into individual samples.

To place the sampling inspection on a systematic basis, each inspector is provided with a "Random Sampling Box"—a metal container divided into five compartments, one for each sample—these being each sub-divided into sections into which satisfactory and rejected units are placed.

The results of sampling are recorded on a special form a separate sheet being allocated to each component. The top section is devoted to general details of each batch, supplied; the middle section records the results of sampling; and the lower section shows whether or not the batch was accepted, the authorisation for this decision, and any relevant remarks.

A further form serves as a general guide to inspection, and as a graphical summary of progress. On the left are detailed the points to be noted in inspection, those of especial importance being emphasised as "Key Points". The main part of the form is used as a chart, the total number of defective units in the first two samples (60 units) from each batch being plotted successively on the chart field. A useful guide to quality over a period is thus established; and as a separate chart is maintained for each supplier of each product, the comparison between suppliers is of value—particularly so when further contracts are being negotiated.

These forms, together with the component drawing and any other relevant "paper-work" are filed under the component drawing number, so that information relating to any particular component is readily available.

Vendor Certification: Efforts are now being made, with some success, to induce our suppliers to apply to their own inspection the same principles of sampling as we ourselves use, and to forward with each delivery a certificate detailing the results of this inspection. Any check which we may then impose will, in effect, be an extension and confirmation of the suppliers' own inspection rather than, as now, an unrelated parallel inspection. In those cases where Vendor Certification is in use, the "pooling" and interchange of information has been of great value to both parties.

The sub-contractor quality rating in the Rolls-Royce Co Ltd., UK, is described below:

Conditions applied

(a) Items released in "Standard" batches are the only ones considered in calculating ratings. (A "Standard" batch contains only items released by the sub-contractor as correct to drawings.)

(b) A sub-contractor is rated when he has supplied a minimum of 4 standard batches on each of 6 different parts.

(c) To ensure that the ratings are, as far as possible, representative of the current performance of sub-contractors only the latest 3 standard batches received on each part are considered.

Method

(a) Applying the above conditions: Obtain the totals of Items received, Items defective, Batches received, and Batches defective.

(b) Divide "Items defective" by "Items received". The result is FRACTION DEFECTIVE (ITEMS)

(c) Divide "Batches defective" by "Batches received". The result is FRACTION DEFECTIVE (BATCHES).

(d) Multiply FRACTION DEFECTIVE (ITEMS) by FRACTION DEFECTIVE (BATCHES).

Apply the resulting value to the following ratings.

Ratings

Value obtained		*Rating*
Between 0.000 and .005	=	A
" .005 and .020	=	B
" .020 and .050	=	C
over .050	=	D

The rating A, B, C and D are in a descending order of merit.

Example

For the purpose of this example it is supposed that the following quantities apply:

STANDARD BATCHES RECEIVED
48
STANDARD BATCHES CONTAINING DEFECTIVES
12
ITEMS RECEIVED
4,000
ITEMS DEFECTIVE
160

FRACTION DEFECTIVE (ITEMS) = $\frac{160}{4,000} = .040$

FRACTION DEFECTIVE (BATCHES) = $\frac{12}{48} = .250$

$.040 \times .250 = .010$

This value falls between .005 and .020 and is therefore in rating 'B'.

In Massey-Ferguson Tractor Co., UK, graphical records are maintained as to suppliers' quality and there were cases where the quality of items had improved, in the sense rejections came down after communication of the results of quality evaluation to the supplier.

Summarising, it must be emphasised that in most of the factories visited in Japan, USA and UK, there was a good system of incoming material quality evaluation and communication of the results to the supplier. There have been instances where the factories have sent their personnel to the premises of vendor in assisting in their quality problems. The situation has been ably summarised by the quality control Manager of Massey-Ferguson: "We do not consider a problem cleared until the supplier's process has been altered to our satisfaction, quite apart from the delivery of corrected components. For this reason liaison is maintained not only with the supplier but also with the several departments in the factory for any latent defects being shown up while processing."

Process Control

Process Control refers to the procedures adopted to evaluate, maintain and improve quality standards in several stages of manufacture. In all the factories visited in Japan, USA and UK, there were good procedures of evaluating quality in the various stages and schemes for corrective action whenever necessary. Some of the procedures are discussed below.

In industries in Japan, "The control charts, sampling inspection and design of experiments which are the fundamental techniques of Quality Control are rather widely used among various classes of people, and are not considered as anything new" (quoted from an article, "Total Quality Control at Toshiba"). This is true not only in bigger companies like Toshiba and Toyo Rayons, but also in small companies (employing about 250 people) like Tohoku Works Ltd., and Toyonakayo Communication Equipment Manufacturing Co., visited by the Team.

Some other techniques applied in Toshiba are sensory inspection and adoption of check system: "We judge colour, shape, or sound, etc., through our 5 senses, and we carry out experiments and analyses concerning them. The effect of materials on the tone quality of records, preference test of the colour of TV cathode ray tubes are such examples, and we have obtained interesting results."

An experiment by means of paired comparisons was made through the ears of 4 examiners in order to test the preference of the tonal quality of record disks, taking as the factors the material of the disks, manufacturing conditions and the order of pressing. The analysis of variance of the experimental results revealed that there was a significant difference in materials. Besides, in the case of pressing with

a certain material, different tonal qualities resulted with different orders of pressing.

Self-inspection becomes especially necessary in non-mass production areas. Mistakes during the design stage also lead to serious consequences in production, and so a check system for design becomes especially important. It became possible through the use of this check list to prevent design and manufacturing errors and is found very effective in the control of quality.

The process control system at Toyo Rayon Co. Ltd., is described as follows:

"The objective of process control lies in maintaining the optimum conditions and procedures. Their evaluation is effected by applying the standard of intermediate products as the measure.

"Main procedures in our plants have their work standards. The work standard bears the optimality by which the prescribed quality can be worked while being simultaneously vested with the character of delegation of authority. Hence, the work sheet may be said as being comprised the above-mentioned dual elements. Especially, due consideration is shown to such factors as defect prevention, prescription of abnormality counter-measures, check system, as well as the interrelated aspects of education and training.

"More particularly, the evaluation of the work results is controlled by the responsible personnel empowered with the delegated authority of work order, by resorting to the method of the control chart, whereas, as regards work requiring instantaneous adjustment, information is communicated through the skip route, thereby expediting the disposal or dealing of the matter. These procedures are managed en bloc in the chart room. The chart room is the place where various problematic points of quality and cost are concentrated. Questionable and disputable points of quality and cost are systematically worked out in this room so as to be linked on a well-laid plan."

The description of the chart room in Toyo Rayon is as follows:

"Each plant has a meeting hall named chart room for the purpose of discussing and studying problems concerning quality of products, or yield, checking the project-planning with Ganth-chart of main subjects, as well as exchanging such field information in regard to daily operations as production scheduling, alteration of manufacturing conditions, plant experiments and work improvement. Our Company's first chart room was set up at our Mishima plant in 1958, which rapidly stimulated all other plants to also adopt the Chart Room System.

"The Chart Room which has now come into practical use as centralized control system, is also expected to function as computing centre in future. Main objectives of our chart room are considered as follows:

(a) Process Control by control chart;
   —quality (quality characteristics of raw materials, final products and manufactural conditions)
   —cost
   —effective measurement (productivity)

(b) Process analysis;
   —between different products
   —within similar products (time series)
   —trouble shooting

(c) Process improvement;
   —plant experiment (material, equipment and operation standard)
   —change in manufactural conditions (material, equipment and operation standard)

(d) Project planning;
   —plant experiment
   —pending problem
   —improvement, plant investment
   —budget
   —production rate

(e) Administration of conferences;
   —emergency meetings
   —regular meetings
   —daily meetings

"To fulfil these itemized functions, the chart room possesses numerous useful charts, e.g., charts or control, charts of quality characteris-

tics for raw materials, final products, and Ganth-charts for project-planning, tables of quality characteristics, process capability graphs, so that it is able to play an important role as a control centre for clarifying all forms of trouble and facilitating exchange of communications."

In addition to the techniques like control charts, sampling inspection and simple design of experiments, the Tohuku Works Ltd., (employing about 250 people) in Japan, manufactures of shuttle body (part of sewing machine) has used such statistical techniques like "method of discriminent function" for prevention of article of inferior quality of heat treatment, 'Trend Analysis' for maintenance of accuracy for cutting and grinding machines, adoption of sampling inspection by variables which takes into consideration 'variation' also, by use of range, use of 'Weighing Designs' in accuracy inspection of gauge block.

The following items are worth mentioning in the application of statistical quality control techniques in industry in Japan (Quality Control in Japan *ibid*).

(a) A great number of control charts and histograms are being drawn.

(b) The method of analysing bulk shop data statistically by means of the binomial probability paper is being utilised.

(c) The design of experiments are being fairly well applied to industries especially in the factory shop. Especially the design based on the "tables of orthogonal arrays", established by a group led by Gen-ichi Taguchi, has attained remarkable results not only in the shop but in co-operative experiments between suppliers and users of material.

(d) Statistical methods are frequently being used to find more logical methods of sampling, testing and chemical analysis of physical materials (especially bulk materials).

The average number of control charts used per plant is shown in Table 1. The Table clearly shows the popularity of use of control charts.

Sensory inspection—taste, smell, sound, touch, etc.,—are on the increase in Japan for the last three years. The Table 2 summarises the tests performed by the Japanese Union of Scientists and Engineers (JUSE).

TABLE—1

The Average Number of Control Charts Used Per Plant

Industry	No. of employees			Average
	More than 1,000	150-1,000	Less than 150	
Ferrous & non-ferrous	810	164	—	554
Chemical	695	405	134	462
Textile	321	115	—	188
Electric machinery	491	—	—	481
Mechanical	1,170	230	—	387
Food & tobacco	416	199	—	188
Others	42	141	—	111
AVERAGE	628	194	41	366

TABLE—2

Table of sensory tests performed by the Sensory Test Sub-committee of JUSE (up to October, 1957).

Sense	Object examined	Method
Touch	Stiffness of textiles	Scheffe's method
Hearing	Records	Scheffe's method
	speakers	Bradley's method
Sight	Patterns of textiles	Scheffe's method
	Patterns of glass plates	Rank-order, scoring, Bradley's method
	Whiteness of starch	Rank correlation
Smelling	Freshness of canned foods	Scoring, Bradley's method
	Edible oils	Thurstone's method
	Sake (Japanese wine)	Bradley's method
	Liquid pharmaceuticals	Scheffe's method
	Orange juice	Fisher's scoring method
	Biscuits	Methods of Scheffe, Bradley, and Thurstone
	Cigarettes	Bradley's method
	Miso (bean paste)	Rank-order scoring method

In Eastman Kodak Co., Ltd., USA, the statistical quality control technique utilised and field of application are shown in Figure 45.

RESEARCH & DEVELOPMENT	—DESIGN OF EXPERIMENTS—SAMPLE SURVEYS —DATA ANALYSIS —REGRESSION & CORRELATION
DESIGN	—DESIGN OF EXPERIMENTS—DATA ANALYSIS —STATISTICAL TOLERANCES—FITS —COMPONENT LIFE TESTING —RELIABILITY ESTIMATION
PRODUCTION	—VENDOR CERTIFICATION —PROCESS CAPABILITY STUDIES —"EVOP" —CHARACTERISTIC VECTORS —SAMPLING PLANS—CONTROL CHARTS —QUALITY AUDIT—FEEDBACK —RELIABILITY DEMONSTRATION & PREDICTION
CUSTOMER	—ANALYSIS OF RETURNS —FEEDBACK

Fig. 45—Statistical Quality Control Application

Control charts were seen on many important characteristics. Also Wald-Wolfo Witz sampling plans were used at the end of each line.

In Radio Corporation of America in USA control charts and sampling plans are used on routine basis for process control purposes. While accepting material from one section to another, when a lot is rejected on the basis of sampling plan, a rejection notice is issued, a specimen of which is shown in figure 46, and the lot after rectification is resubmitted.

Statistical Quality Control techniques and procedures were pioneered at Western Electric Co., USA, over 25 years ago. Even today they rely on Statistical Quality Control to achieve high quality, long-lasting products at the lowest possible cost—while maintaining uniform production volume in conformance with design specifications.

At Western Electric extensive use of control charts for process control were noted. Figure 47 gives an idea of the extensive use of control charts.

The process control layout which gives all the necessary details regarding the processes is reproduced in figure 48.

With such large number of charts, it becomes essential to know whether the information provided by these charts is effectively utilised. For this purpose several schemes are in operation. The control charts are analysed by process checkers. The specimen form used for this purpose is shown in figure 49. Also the control charts in the shops are surveyed regularly. The form used for this purpose is shown in figure 50. A specimen report issued as a result of this survey is reproduced below:

Re: Procedural Audit of Process Control Charts in the Silicon Carbide Varistor Area.

During the last few days the process control charts in your area were surveyed for the second time in our current series and the following items were noted:

1. Per cent defective charts on the 312D and E (2692—1 through 5 and 2692—10 through 13) were not plotted up to date.
2. Two instances were found where charts other than those specified were being used.
3. Charts on voltage shift of the 312D and E were not being kept.
4. Not all out of control points were being marked and initialed as prescribed.

I trust that you will either take action to remedy the above situations or bring your reasons for not doing so to my attention.

K. S. Stephens—4320

Copy to:

Dept. 2320
Dept. 4320 ;

In Sonotone Corporation, USA, the process control functions in each department are: (i) acceptance of the product and (ii) in-process control. The acceptance of the product from one department to another is done by the use of sampling plans. The in-process control function is performed to facilitate the shop personnel in adjusting and setting machines and to concentrate on trouble spots. While acceptance of the product in case the lots are rejected, they are sent back to the department. After suitable action it is resubmitted for acceptance.

The statistical analysis of production data in Rolls-Royce Co., UK, is done on routine basis. Also rejections, rework, scrap, cost of scrap are analysed on power-Samas machines. According to the company this gives indication where efforts should be directed.

In Massey-Ferguson Tractor Co., UK, the application of Statistical Quality Control techniques are described, as explained by the Quality Control Manager.

"Maximum emphasis is placed on the use df statistics to assess and reduce the variability of the process, but for day-to-day control we place more emphasis on the knowledge and experience of our personnel—keeping statistics to the minimum necessary to ensure efficient operation.

All machines should be passed through Process Capability Studies. This commences with a distribution diagram at the demonstration stage for each dimensional element, and finally, the installation for an initial period of an

REJECTION NOTICE

PROCESS CONTROL

DATE
SHIFT

TO:		OPERATOR	EQUIPMENT
SUBJECT		TYPE	TIME
LOT SIZE/NO.	SAMPLE SIZE	QUALITY CONTROL INSPECTOR	
DEFECTS			

☐ DETAIL SUBJECT MATERIAL MANUFACTURED ONE (1) HOUR PREVIOUS TO THIS INSPECTION AND RESUBMIT TO QUALITY CONTROL FOR RESAMPLING.

☐ DETAIL MATERIAL FROM WHICH SAMPLE WAS DRAWN AND RESUBMIT TO QUALITY CONTROL FOR RESAMPLING

☐ HOLD SUBJECT MATERIAL FOR ENGINEERING DISPOSITION

ACTION	ENGINEER

☐ SHUT DOWN EQUIPMENT FOR CORRECTIVE ACTION

ACTION	MACHINE ATTENDANT

THIS SECTION MUST BE COMPLETED BY MFG. - RETURN MATERIAL WITH REJECTION NOTICE TO PROCESS CONTROL

TOTAL UNITS DETAILED _____ TOTAL UNITS DEFECTIVE _____	OPERATOR DETAILING

QUALITY CONTROL USE ONLY

DATE RESUBMITTED _____ DATE RESAMPLED _____

REMARKS

☐ ACCEPTED

☐ REJECTED

SD 207

Fig. 46—Specimen of Rejection Notice, Radio Corporation of America.

	1-54	1-55	1-56	1-57	1-58	1-59	1-60	$\bar{X}$&R	P	NP	Misc.	Engr. Studies	Total Process Control & Inspn. Layouts
1. 2100 Shops	12	12	24	44	39	34	36	26	6	...	4	...	5
2. Rectifiers	39	43	91	29	37	36	38	21	2	15	...	...	7
3. Sm. Runners & B. Lamps	6	36	66	89	83	97	96	53	13	9	21	...	7
4. Repeaters	62	111	60	141	134	109	138	76	20	39	3	...	7
5. General Purpose	39	102	122	139	100	128	115	102	...	9	4	...	11
6. Resistance Lamp	97	128	180	193	202	193	199	94	48	29	28	...	42
7. Glow Lamps	...	...	...	...	72	83	81	25	20	...	33	3	9
8. H. F. Miniatures	110	175	263	528	388	269	181	50	112	...	9	10	13
9. Miniatures	52	58	84	113	209	237	245	111	107	2	9	16	37
10. Carriers	...	...	...	...	...	...	360	297	16	10	25	12	52
11. Chemicals (E&W)	30	52	22	46	28	84	91	78	7	1	5	...	16
12. Grids	15	28	74	143	175	192	98	59	2	37	...	...	9
13. Glass Piece Parts													
14. 2200	112	100	96	271	329	323							
15. Transistors	...	...	...	...	...	...	100	49	15	...	35	1	14
16. P.C. Transistors	...	...	...	...	...	...	52	17	30	...	...	5	5
17. Grown Jct. Trans.	...	...	...	...	...	...	254	135	101	6	7	5	32
18. Alloy Transistors	...	...	...	...	...	...	71	21	...	...	...	50	...
19. Diffused Transistor	...	...	...	...	...	...	21	4	11	2	2	2	8
20. Headers	...	...	...	...	...	32	38	24	6	6	1	1	11
21. Sil. P. C. Diodes	...	...	...	...	...	59	75	30	39	...	2	4	17
22. Ge. P.C. Diodes	...	...	...	...	25	41	29	87	119	74	33	7	...	5	12
23. Sil. Alloy Diodes	...	...	...	...	...	54	71	12	23	12	9	15	12
24. Dif. Sil. Diodes (Prod)	...	...	...	...	...	...	110	...	...	...	4	106	...
25. Dif. Sil. Diodes (DCL-BLX)	...	...	...	...	...	35	79	55	18	...	1	5	27
26. Ge. & Sil. Processing	...	...	...	...	...	...							
27. 2300	92	83	107	111	97	92	120	37	78	...	...	5	26
28. Planar Triodes	...	...	...	30	87	121	180	152	...	...	...	28	29
29. Travelling Wave Tube	153	166	190	192	136	62	115	91	19	2	3	...	33
30. Reflex Oscillators	71	72	207	225	256	228	218	134	69	14	1	...	49
31. Thermistores	110	139	265	440	...	...	...	...	...	...	...	...	...
32. Mercury Sw. & Relays	...	...	...	...	472	460	262	173	69	17	3	...	33
33. Mercury Switch	...	...	...	...	190	170	81	49	24	8	...	...	8
34. Mercury Relay	...	...	...	...	...	...	...	...	...	...	...	...	...
35. CuO & SiCVaristors	39	110	148	247	164	173	107	42	65	...	...	...	16
36. Sil. Car. Varistor	...	...	...	...	46	47	48	28	20	...	...	...	8
37. Cu Oxide Varistor	...	...	...	...	500	432	40	23	17	...	...	...	9
38. Dry Reed Switch	66	211	324	454	462	432	321	166	139	16	...	...	20
39. Switchboard Lamps	173	389	377	435									
TOTALS	1553	2335	3103	4399	4717	4714	4160	2308	1129	241	209	273	584

Fig. 47—Statistical Quality Control—Status of Charts & Layouts (Nov., 1960)

MASTER AP 473—JM9 MANUF. CB 2136 FOR USE WITH S1 213 Date 2-15-61 No. IL 3172
PROD. ENG. GC-5210 Q.C. Eng. BID-4320 Sheet 2 of 2 ISSUE 1
SERVICE ENG..... MANUFACTURING DEPT. GLOW LAMPS

Operation	Characteristic	Code	Drwg. No.	Chart No.	Type of Chart	Sample Size	Frequency	Origin of Date	Record of Date	Facilities	Note
5. Electrical Test	(f) All dropouts	423C, 432B, 447A, 6140 & 453A	A-499813 (6140)	(e) X.R Chart (f) (P) Chart							
6. Bulb test	(a) Sidewall strain (Inside & Outside) (b) "B" test		P-499277 (423A) A-499812 (423C) A-539522 (447A) A-499651 (453A) A499812 (6140)	91 for a. 92 for b.	(a) X,R Chart (b) P Chart	5 tubes for a and b.	Daily for a. One point a week on 5 sample for b.	Process Checker	(a) AP-510 F data sheet (b) AP-333-Y data Sheet	(a) Sidewall strain polimeter. (b) B A 770959-2 Bulb strain equipment	
7. Mechanical test	(a) All dropouts (b) Code marking shall be legible and correctly placed (c) Loose particles (d) Glass Cracks (e) Getter touching glass (f) Defective or cracked bulb (g) Defective leads (Outside of tube) (h) Defective tip-off (stringy, long, broken shape). (i) Bent or defective pin (j) Distorted elements (Inside of tube) (k) Insufficient getter flash (Unpainted codes) (l) Arcing under ceramic		A-499277 (432A) A-499812 (423C) A-539522 (447A) (A-499651 (453A) A499812 (6140)	93 for a. 94 for b-1	(a) P (b) (c) C (d) H (e) A (f) R (g) T (h) (i) (j) (k) (l)	All tubes for a. 10 tubes for b to 1	Daily for a. each day plot 2 points for b-1.	Process Checker	AP-333-Y data sheet	Visual for a-1	

Fig. 40—Process Control Layout

Process Checker

A. *X, $\bar{X}$ or Chart Analysis (Circle One)*

1. Do any points fall outside of 3 sigma limits
2. Do 2 out of 3 *successive* points fall in Zone "A" or beyond
3. Do 4 out of 5 *successive* points fall in Zone "B" or beyond
4. Do 8 *successive* points fall in Zone "C" or beyond
5. Do fifteen or more *successive* points fall in Zone "C"
6. Is patten going up
7. Is pattern going down

B. *R Chart Analysis*

1. Do any points fall outside of 3 Sigma limits
2. Do 2 out of 3 *successive* points fall in Zone "A" or beyond
3. Do 4 out of 5 *successive* points fall in Zone "B" or beyond
4. Do 8 *successive* points fall in Zone "C" or beyond
5. Do fifteen or more *successive* points fall in Zone "C"
6. Is pattern going up
7. Is pattern going down

C. *General*

1. Do $\bar{X}$ and R chart points move in the same direction
2. Do $\bar{X}$ and R chart points move in opposite direction
3. Do out-of-control points lack marking with "x's"
4. Do out-of-control points lack acknowledgement
5. Is this chart plotted at other than the specified frequency
6. Do you feel that the specified frequency should be changed (if yes, comment)

D. *Specification Check*

1. Is there conflict between the specification limits and present process? (If yes, comment)

SUPERVISOR

E. *Use and effectiveness*

1. Is this chart useful
2. Is this chart current
3. Is this chart required for process control or for information (Enter either PC or I)

(Place a Y or an N for no in the appropriate space)

			A.X.X, or P (Circle one)	B. R Chart	C General	D	E. Use		
	PCL & Chart No.	Code	1 2 3 4 5 6 7	1 2 3 4 5 6 7	1 2 3 4 5 6	1	1 2 3	Comments	
1									1
2									2
3									3
4									4
5									5
6									6
7									7
8									8
9									9
10									10
11									11
12									12
13									13
14									14
15									15
to 30									to 30

Fig. 49—Quality Control Chart Analysis

See item (s) checked below.

—This chart plotted and used correctly.

—Chart is not being plotted currently

—Chart not plotted to specified frequency

—X's not marked on out of control points

—Dates not recorded

—Out of control conditions not initialed by supervisor or other responsible person

—Chart not placed at operation

Fig. 50—Shop Control Chart Survey

Average and Range Chart when the machine is turned over to Production.

The Process Capability Studies are also vital to ensure the education of Production Engineering personnel on the variability aspect of the combinations of tooling and cutting speeds being planned for the future. This education is the only effective way of finally educating the design engineer for improved design for quality.

The Inspection Procedures Section should begin work after the Process Capability Study has been carried out, and it is their responsibility, in consultation with line supervision, on issue a control procedure for each inspection station.

The full operation of Average and Range Charts is a very valuable tool in establishing the variability of a process as affected by running time, tool wear, material variations or deterioration of the machine. They do not, however, favour the use of these permanently on our type of production, although their contribution is vital in the initial clearance of a process or as an investigation tool to be used where a process variability increases.

The charts we prefer for day-to-day control are the far simpler Number Defective Type. These maintain the visual aspect for operator interest, without losing the judgment and skill of the inspector. They also provide a record for future analysis.

It was by about 1924 the first steps were taken in the General Electric Co., UK, to apply statistical methods to the study of data collected as a routine in factories, and to develop methods of presentation which would assist all concerned with the supervision of manufacture.

The handbook, 'Quality Control Chart Technique, when Manufacturing to a Specification', issued by the General Electric Co. of England in 1944, has proved useful in many industries. It indicates clearly the nature of the shortcomings of a process if consistent conformity to specification is difficult to achieve. This handbook is now published by the British Standard Institution as B.S. 2564 (1955).

Regarding the use of Control Charts Dr. B. P. Dudding, pioneer in the use of statistical methods in GEC (and also other industries in UK) says that "it should be emphasised that the greatest service that control charts can pro-

vide is lost if they are merely kept in the office or desk of a supervisor. In their simplest form, they should be exhibited in the organisation in close proximity to the process from which the data were derived. On many occasions, both in GEC and other factories, the exhibition of results in this manner has raised efficiency by creating an interest for operators of modern processes where the nature of the process has eliminated the kind of interest which was inherent in the work of the artisan. In addition, exhibition of control charts in different sections of a manufacturing organisation does much to reduce inter-departmental suspicions, and to discourage the practice of 'passing the buck'."

Dr. Dudding has pointed out that "it is unfortunate that the word 'quality' (in Quality Control) has always been associated with Control Chart Technique, for this association undoubtedly retarded the application to other classes of industrial data where its use would have been as valuable as, or even more valuable than, in the narrow field of factory inspection."

In Corah Ltd., UK, waste charts (with targets) are kept in each section. Every roll of knitted material is inspected and mended. A quality control inspector checks the work of each inspector randomly. The defects found in various rolls are recorded and sent to the manager.

The Central Laboratory in Beecham's Ltd., UK, issues the quality control procedures to the various laboratories. Any changes in the procedures are worked out at central laboratories. The statistical interpretation of production data is done by the Research Department. During production they do not apply any statistical techniques.

Product Control

Product Control refers to the schemes for evaluating the quality of the outgoing product (including finished products in stores and warehouses), analysis of information and data obtained from field (where the product is in actual use) and feeding back to the production processes, as an endeavour for constantly attempting to improve upon product quality. In all the factories visited abroad, particularly in USA and UK, there were good procedures of product control, some of which are described below.

The Outgoing Product Quality Rating programme (OPQR) developed by H. F. Dodge and M. N. Torrey of the Bell Telephone Laboratories was seen in operation in Western Electric Co., and Bristol-Myers in USA. The OPQR programme in Bristol-Myers (based on a paper, Outgoing Quality Rating in Practice—W. C. Frey and E. R. Ott) is described below:

In the Bristol-Myers OPQR programme, each product is sampled daily just before being placed in the shipping cases. The samples are then inspected carefully and a demerit rating assigned according to the type and magnitude of defectives observed. The rating is done by a department which is independent of manufacturing.

The procedure is certainly *not* a police function—the rating is primarily for information and feedback purposes. It is an information service to Top management, providing an objective overall evaluation of outgoing product; without such an evaluation, it is difficult for management to have a sense of security. The management officials of most companies are justified in their confidence that their staff is geared to produce high quality goods which are economically consistent with the price at which the merchandise is to be sold. But how many such Managements can claim accurate information about the exact nature of their product quality as it goes to the customer even though it may have had "usual" 100% inspection? How many Managements know, for example, how many inoperative radios leave their plant; how many refrigerators leave with scratched doors; how many phonograph records have audio imperfections; how many of their solder joints are defective?

Management is entitled to a good objective summary of its quality characteristics and not just an assurance that everything has been inspected 100% (Italics ours).

Perhaps an even more important function of the rating programme is to pinpoint areas in manufacturing which warrant attention, whether from raw materials (or components), process adjustment, engineering design, inspection, or other reasons. It provides a much faster and surer method of getting to trouble areas than does the alternative method of following production step-by-step from the beginning on

through successive stages. The trouble spots may be "spots" in the carton, crooked labels on a cosmetic package; or whatever type of defect; the rating programme (which examines carefully relatively small samples independently of production) will quickly indicate the place and nature of attention needed. It is for these reasons that this rating programme can be an effective vehicle for introducing and extending a total quality control programme. The form of the plan as we use it includes the selection of small samples from each day's production (from each manufacturing line) and the careful examination of them by an independent checker. These few (sometimes twenty and never more than forty per day per manufacturing line) are examined and the observed defects are recorded as in the attached OPQR Weekly Summary form (Figure 31.)

Defect Classifications and Classes: What is a defect? What is a non-conforming unit? These are always difficult questions to answer especially for visual defects. A label upside down clearly is not intended; dirty bottles and wrinkled labels are not desirable but there are all degrees of dirty bottles and wrinkles. A discussion of the types of defects which might possibly be found in one's product is rather academic until actual facts are obtained. Thus, one of the first steps agreed upon by the B-M committee, appointed to activate the programme, was to obtain this information. Members of this study committee represented top management, sales, manufacturing and quality control.

(A) Two of our standard products were selected for an initial study.

(B) Fifty sample bottles of each product were collected throughout each day for a period of one week.

(C) These samples were examined carefully by an independent checker: each bottle with any deviation from perfection was tagged and saved for the committee.

(D) The Study Committee examined the visual defects found and added to the list some of which might be found.

(E) Defects were then classified into four categories similar to those used by Dodge and Torrey. A demerit rating was attached to each of the four defect classifications.

(F) The four defect categories accepted were the following :

(a) **Minor:** These are items which are not perfect; they are objectionable, but so slightly objectionable that management would agree that these items should not be removed from the production line, if observed. However, it is desired that corrective efforts be made to reduce the number of subsequent defects of this category. (Slightly crooked labels are typical.)

(b) **Moderately Serious:** These are non-functional package defects of a somewhat more serious nature. They would probably be noticed by the customer, although it is doubtful that they would result in loss of goodwill. They are sufficiently objectionable, however, to require line inspectors to call them out of production—they should not reach the customer. (An upside down, dirty, or wrinkled label are examples).

(c) **Serious:** These are appearance defects or functional defects which might possibly result in loss of a customer but would certainly result in loss of goodwill. (Broken plastic cap, short fill, etc. are examples).

(d) **Very serious:** This category is reserved for those rare defects which could conceivably result in bodily injury.

After the categories were established a demerit rating value was assigned to each category in accordance with its estimated importance. (In our schedule we rated Minor = 2 demerits, Moderately Serious = 10, Serious = 25 and Very Serious = 50.) Control charts for the overall demerit rating were established (per hundred units of each product) according to the principles described in the paper by Dodge and Torrey. (See Table on page 65).

In an initial discussion it is the common experience that it is difficult to get agreement on levels of defects which are tolerable. Every company official, whether he represents Manufacturing, Sales or Management, is reluctant to accept quality standards which are short of per-

| | | D Very Serious | | | C Serious | | | B Moderately Serious | | | | | | | | | | A MINOR | | | | | | | | | |

Computation of Quality Standard Level (D_{100}) and Control limits ($3\ \sigma_{100}$)

Class D Defect = 50 demerits = w_D D_{100} = Demerits per 100 units
Class C Defect = 25 demerits = w_C
Class B Defect = 10 demerits = w_B
Class A Defect = 2 demerits = w_A

From the Dodge-Torrey Article, the D_{100} and $\sigma 100$ is computed as follows—

$$D_{100}=100\ \frac{(w_A\ d_A + w_B\ d_B + w_C\ d_C + w_D\ d_D)}{n}$$

where d_A, d_B, d_C, and d_D are the numbers of Class A, Class B, Class C, and Class D defects respectively, found in the sample in

$$\sigma_{100} = \sqrt{\frac{100\ [(w_A)^2\ d_A + (w_B)^2\ d_B + (w_C)^2\ d_C + w_D)^2\ d_D}{n}}$$

Defect Class	Demerit Value (w_i)	Defects Found (d_i)	Demerits ($w_i\ d_i$)	$(w_i)^2\ d_i$	$n = 2400$
D	50	0	0	0	
C	25	1	25	625	
B	10	60	600	6000	
A	2	302	604	1208	
			1229	7833	

$$D_{100}=\frac{100\ [50\ (0) + 25(1) + 10(60) + 2\ (302)]}{240} = 100\ \frac{(1229)}{2400} = 51.20 \text{ demerits per 100 units}$$

$$\sigma_{100} = \sqrt{\frac{100\ [(50)^2\ 0 + (25)^2\ 1 + (10)^2\ 60 + (2)^2\ 302]}{2400}} - \sqrt{\frac{783300}{2400}} = 18.1 \text{ demerits per 100 units}$$

Control Limits $= D_{100} \pm 3\ \sigma_{100}$
$= 51.20 \pm 3\ (18.1)$
$= 0$ and 105.5 demerits per 100 units.

fection or to agree that even a single serious defective can be tolerated. One of the arguments which might be used to refute this concept relates to this question: "What per cent of aeroplane accidents are tolerable in commercial flights in the US?" The immediate answer, of course, is "none"; however, we recognize that if this is really the answer, then all such flights must be grounded. It was in somewhat this approach that it was possible to establish initial working standards of quality for the Bristol-Myers' products.

Within each defect category, we grouped defects which were related to each machine within the plant. For example, if we look at the OPQR Weekly Summary, we see that many of the defects come from the labeller. This grouping by machine is helpful in providing an easily understood information feed-back procedure. In our plant, Outgoing Product Quality Rating Reports are published weekly. The report consists of a dittoed Rating Control Chart plus a detailed listing of the defectives which led to the overall rating value. Occasionally, when the weekly report stimulates interest in certain production areas, daily reports are furnished on critical items in that area so that the interested department has an independent detailed analysis of difficulties where attention is being concentrated.

Additional Applications: One important function of this information is to compare the quality of current production with previous production. Is the quality improving, holding steady, or getting worse? How does the day-shift quality compare with the night-shift or

vice versa? Is the quality from Line 1 similar to Line 2? If there is marked difference, where is the major departure? The OPQR provides ready answers to these and other similar questions.

Occasionally a defect is found on the shelf of a drug store—and appearance imperfections will always be found. It is important to know whether this was something which might represent an epidemic at the time the product left the plant, or whether it is something which developed subsequently. Here is where the production man who may have been somewhat sceptical of the programme initially finds it very useful to quote the OPQR records which provide objective testimony that certain defects developed after the product left the plant. It is also important to know systematically and regularly about how many off-standard items are being shipped, so that when, for example, a field complaint is received, you can tell the Vice-President that not all the toothpaste tubes went out empty.

The product quality index is computed as follows in Joseph Lucas Ltd., UK. This index is based on four items: (i) Scrap, (ii) Rectifiable faults, (iii) Manufacturers' Returns, and (iv) Road Returns. Items (i) and (ii) refer to within factory operations, item (iii) is from other manufacturers who use their product (e.g., car manufacturers) and item (iv) is from individual customers who use their product. For each of the item a target is set every month and it is compared against the actual performance, i.e., $\frac{\text{Objective}}{\text{Achieved}} \times 100$. Then a simple average of all the items is taken, which is called the Product Quality Index. This is done for each product.

In Rolls-Royce Co., UK, the details of all the engines (with various airlines) with regard to hours flown, removal rate (to be pulled for overhaul before the expiry time) are tabulated. The information is classified according to airline operators and the results are shown in a graph. Various airlines, for the same engine, give different readings. These informations give details of performance of their engines.

In Massey-Ferguson Tractor Co., the Product Control aspect was explained by the Quality Control Manager as follows:

Inspection and Production laboratories enable the quality manager to control the quality of the plant's production, but there is still one important aspect of his operation left uncovered, namely customer satisfaction. All his organisation is directed at this functional result and he must have first-hand knowledge of the company's products judged by this yardstick.

It is therefore necessary to form a third function, in which is vested this responsibility for understanding the customer position. We term this Product Quality, but once again the title is unimportant and it is only the facility that matters.

The Product Quality Engineer must not only be fully aware of every aspect of the current customer position, but also to have carried out sufficient investigation to establish the cause of failure and take the necessary remedial action. The Service Division will always be able to provide data on the extent of any complaint, as well as producing failed samples for examination. They are not, however, at their best in establishing the exact reason for failure and this responsibility must be taken over by Quality Engineer.

Product Quality Department is basically a coordinating department. The two engineers in the department, namely Failure Investigation Engineer and Technical Investigation Engineer carry out very much the same work, the main difference being that the former operates from the physical examination of returned failures from service, and the latter from distributors' complaints. These Engineers utilise Stoneleigh Product Training Ground, Distributors' territories, or any other available source of knowledge, in assessing the action necessary to cure a Service problem.

Beecham's Ltd., UK, evaluate the quality of their soft drinks as they are being sold by market pickups twice annually.

Non-Manufacturing Applications

The non-manufacturing applications of statistical quality control techniques, refer to the application of statistical techniques in all other fields of industrial activity except production

(including Incoming Material Control, Process Control and Product Control). However it was not possible for the Team to make investigation of such applications in detail. Whatever information that was gathered during discussion is summarised in succeeding sections.

In Toshiba, Japan, an instance of the application of experimental design in Market Research was given. Also during discussion with the experts in the field (in Japan) an instance of the application to a maintenance problem was mentioned.

A separate statistical service section exists in Eastman Kodak Co., Ltd., and Bristol-Myers Co. Ltd., USA. This department not only services the Quality Control Department, but also the departments who may require its help. In Eastman Kodak Co., Statistical Quality Control techniques are applied to Research and Development, Design and Customer returns. In Bristol-Myers, "One of the major functions of the statistical group is to provide a service to the research, development, pilot plant and medical departments by assisting in the design of their experiments and clinical trials and in the analysis of their experimental results. Experiments which are not properly designed do not yield valid results. Experimental methods which are fraught with variability provide only inconclusive observations. And haphazard experimentation is wasteful of time and money. It is, therefore, the responsibility of this department to prepare for the Research and Medical groups experimental designs and protocols which will not only provide reliable conclusions, but will also furnish the most information for each experimental dollar spent."

Case Studies

The following case study from Toyo Rayons Ltd., Japan, relates to the improvement of adhesive quality of nylon cords with rubber.

"Numerous intricate problems cropped up at the time of our planning to produce nylon 6 tire-cords. The foremost problems of all lay in improving the adhesiveness of nylon cords with rubber. Through the basic experiments conducted by our research department and the positive activities of the study groups these problems came to be gradually solved, resulting in steady improvement in the capability of nylon 6 tire-cords.

As a result of our untiring efforts the demand for nylon 6 tire-cords witnessed a steady rise and within 1½ years we were able to produce 30 tons per month. The annual turnout for 1959, including yarn and dipped fabric, aggregated to 703 tons corresponding to 5% of rayon tire yarn.

As a subsidiary organ of the Technical Committee, we had the Tire-Cord Sub-Committee in which a Special Counterplan group was appointed to cope with the problems of improvement of adhesiveness. Through the activities of this and other special counterplan organizations numerous improvements such as process capability analysis, design of experiments in the plants and standardization of operation, were accomplished. Thus, adhesiveness has risen gradually by adopting various dispositions.

After analysing the past data concerning the elements of adhesiveness, we ascertained that the amount of resin possesses an important bearing upon adhesiveness. Hence, we controlled the density of the mixture of resorcine, formalin and latex (RFL), searched for the proper conditions of the pressure, and improved the construction. As a result of numerous experiments on the standards of combination and application of raw materials, resin liquid, we ascertained the proper conditions.

By two successive experiments in the plants, the construction of the parts of the press, the circulatory installation of resin liquid, and the distribution of set-temperature were considerably improved. Consequently adhesiveness increased and its variation diminished. As a statistical method, presumption of Box based on the chart of direct arrangement was applied.

As it was discovered that Sodium Solbitol Borate is extremely effective as a Buffer of RFL, we conducted various researches as regards its additional amount and economic effect, and succeeded in raising adhesiveness by 1 kg.

As a result of careful study, we finally established some expedients concerning improvement of precision of examinations, rapidly of feedback, and prevention of the changes which occur in the process.

We are making every effort in maintenance of quality standard and cost reduction by the control of density and content of predipping liquid.

This case study on the cost reduction in the manufacture of transistor headers, is reported by the Western Electric Co., in USA.

A header consists of a basin-shaped kovar platform which has 4 prepunched holes in the base, 3 kovar leads which are positioned singularly in 3 of the platform holes, and a mass of glass retained within the platform cavity which positions and insulates the leads from the platform.

Headers are produced by hand-loading a pre-oxidized kovar platform, 3 pre-oxidized kovar leads, a piece of cane glass, and a piece of glass tubing into each recess of a 7-position carbon fixture.

When loaded, the fixtures make one pass on a conveyor belt through an electrically-heated oven which has an accurately controlled, pre-purified nitrogen atmosphere. In this operation, the glass cane and glass tubing melt so that the molten glass comes in intimate contact with the leads and platform, but is contained by the basin-shaped platform. Following a cooling cycle, the header is as good as, or as bad as, it will ever be.

One of the requirements of a header is that the solidified glass may not lie on any portion of the platform flange, nor may it be concave-shapped by more than .032 inch, as referenced from the platform flange. If this .032 dimension is exceeded, the assembly is junked as a "dip" reject.

Header quality for dips was such that 100% shop inspection was required. Rejected headers averaged 4.5%, with an occasional day's junk at 25%. To approach this complex problem, which was creating back schedules and high merchandise losses, a Header Quality Team was formed. A blanket Cost Reduction Case, 99886, was opened by the Team to introduce process controls, investigate processing methods, evaluate piece part specifications and to introduce appropriate sampling plans to the entire header process.

Due to excessive dip losses, the future necessity of purchasing additional glass-cutting machines to support an increasing programme, and Corning Company's favourable price of pre-cut glass piece parts, E. of M. decided to purchase pre-cut glass. The following specifications were submitted:

Cane:	Diameter	.165	±	.005
	Length	.150	±	.006
	(Essentially the same volume per piece as Western's process)			
Tubing:	Diameter	.285	±	.010
	Length	.120	±	.008
	Wall Thickness	.025	to	.030

Early use of Corning pre-cut glass increased dip losses from 4.5% to an average of 13%.

The Team suspected the cause for dip losses to be the result of excessive variations in length of the 2 glass piece parts from lot to lot. Accordingly, a random sample of approximately 25 pieces of glass from each of 4 bags of cane and 4 bags of tubing was obtained, as received from Corning Company. Each piece was weighed on a sensitive balance and the frequency distributions of glass weights in milligrams were obtained.

These distributions of glass weights showed that, even though Corning met our diameter, length and wall thickness specifications, variations within these specifications, from lot to lot plus the added effect of Corning's commercial tolerance for out-of-roundness, created large total variations in the volume of glass loaded by the operator into each header platform cavity.

In an attempt to evaluate the total effect of dimensional variation, the Quality Team decided to sample 50 pieces of glass from each bag as received from Corning Company (cane: 4000 pieces per bag; tubing: 2000 pieces per bag). Each piece of glass in the sample was weighed on a sensitive balance and a frequency distribution of glass weights was plotted and attached to each bag. As suspected the centers of the distributions for each type of glass differed greatly.

Visual selection of a bag of glass cane and a bag of glass tubing, based upon the attached distribution, was begun so that the predetermined total weight of 205 milligrams (enough to adequately fill the platform cavity to maintain a nominal dip dimension) would be achieved as near as possible. The effect of matching glass

piece part distributions decreased dip losses from 13% to an average of 2.4%.

With this marked improvement, Corning was again requested to change our glass dimensions to :

Cane:	Diameter	.165	±	.005
	Length	.160	±	.006
Tubing:	Diameter	.285	±	.010
	Length	.120	±	.005
	Wall Thickness	.020	to	.025

The net effect of these dimensional changes was to increase the volume of glass placed within the leads, and to decrease the volume of glass placed outside the leads, so that an optimum condition existed during the glass-melting operation. The effect of this dimensional change decreased dip losses from 2.4% to an average of 0.6%. The gradual per cent improvement in losses for dips, and the associated changes to the process was shown in a chart.

Current losses for dips have decreased to 0% resulting mainly from increased operator experience in matching glass distributions. Shop inspection for this defect has been eliminated and only the X-R control chart is used to monitor the process.

Annual cost reduction savings from the elimination of dip losses, based upon an average annual requirement of 6.2 million good headers during the next 5 years, amounts to :

1. Purchase of pre-cut glass parts instead of Western's hand-cut parts	...	$16,700
2. Reduction in dip losses, elimination of 100% and inspection, and reduced Final Inspection	...	$51,300
TOTAL	...	$68,000

Coincidental with the work done to eliminate dip losses, the Quality Team investigated causes for "Concentricity" and "Lead Length" rejects. These losses were found to be the result of worn carbon fixtures caused by mechanical wear during manual loading of the piece parts, and from repeated passes through the furnace. By sampling glassed headers directly from the fixtures, as they immerged from the furnace, these marginal fixtures that were responsible for "watering down" the overall quality from the process were identified and junked. This procedure permitted reduced sampling in place of 100% inspection. Annual cost reduction savings are as follows:

1. Concentricity	...	$31,000
2. Lead Length	...	$11,000
TOTAL	...	$42,000

Further investigation of the process is under way by the Quality Team. These areas and the estimated cost reduction savings are:

1. Substitution of shop sampling in place of 100% inspection for visual defects (bubbles, cracks, etc.).	...	$ 28,500
2. Further improvement in yields from 90% to an estimated 95% (Bulletin yield = 85%).	...	$ 21,000
TOTAL	...	$ 49,500

The total cost reduction savings accruing to this case are :

1. Closed portion	...	$110,000*
2. Open portion (estimated)	...	$ 49,500
TOTAL	...	$159,500

Of significance is the fact that this case was the first one opened in the transistor shop at Allentown. The average rate of return for the next 5 years will be 630%.

An interesting example as to how quality control helped in accurate costing is explained by the directors of N. Corah Ltd., UK.

Bound up with the question of quality standards is that of accurate costing, for the two are inextricable, and in this direction also, quality control, has enabled us to establish valuable new methods. This is perhaps best illustrated by what wasachieved in the departments manufacturing outwear. Here the quality control department was faced with one of its most diffi-

cult assignments. In fact, before they tackled it, the problem was considered insoluble. The normal pre-war method of costing, throughout the industry, was to make up a sample garment, observe the machine settings required to duplicate it and cost it on the weight of yarn required to make a dozen garments. When production was in full swing it would suddenly be noticed that the garments were not coming off the machines according to the planned weight. If they were consistenely overweight, we were producing them at a reached profit. If they were underweight, they might be rejected by the customer—quite rightly. Or again, they might be knitted too tightly, not correspond to the required size and be put through an extra stretching process later, an additional process, which tended to reduce their degree of elasticity. Whatever, the trouble, the machines would be stopped and frantic adjustments made to the settings. When this was a regular occurrence it clearly entailed further production losses.

The quality control technicians spent many months analysing this problem. They recorded the weight of every supply of yarn from the spinners over a substantial period and found that by considerable amounts these were sometimes heavier and sometimes lighter than what was expected for a given count of yarn. It thus became clear that our knitting departments had for years been trying themselves in knots at regular intervals trying to cope with these variations. Co-operation with the spinners very quickly enabled us to reduce these to within acceptable limits and we now have a very tight system of control.

Solving that problem led directly to the next step, that of standardising the manufacture of every garment at each stage in the process. Knitting experiments were carried out to determine the exact machine setting that would ensure the correct dimensions and characteristics in the ultimate garments and knitting specifications were laid down for each. The results were then plotted over a period of six months and necessary adjustments made. The weight element, although still an important factor in costing is thus controlled as a variable production factor. The knitting department sets the machines according to specifications provided by quality control and keeps them going, knowing that any variation in weight either way will be very slight and affect only a very small part of the production. In practice, the variations in weight have been far less than when the knitting department adjusted the machines to deal with them.

6 : Standardization

IN the countries visited, great emphasis is laid on standardisation as fundamental to quality control. The standards formulated at the national and the company levels generally define the quality clearly and often prescribe the means to evaluate the specified quality. Standardisation at the national level is fairly well advanced and a large number of standards have been formulated by the respective national standards bodies.

These standards have led to the specification of quality, reduction of sizes and varieties interchangeability of parts and products and efficient utilization of materials. They have served as a basis for having mass production for mass consumption and have led to significant economics, as would be evident from the following statements quoted by the American Standards Association:

> "There can be no question that the reason America has made such a tremendous progress in all things is largely due to standardization of products, sizes, threads and dimensions for various devices. The saving to the ultimate consumer is beyond comprehension".

It was also of considerable significance and gratification to note the development of company standardisation in these countries particularly in Japan and United States. The company standards are evolved by the companies themselves taking into consideration the requirements laid down in the national standards (where available) and their own production conditions. Besides, the information collected with regard to the process capability, performance etc. are fed back to the design/engineering department with a view to the reviewing the standards and determining the quality requirements of future products. The following description given by the Toyo Rayon Company (with editorial modifications) makes an interesting reading in this respect:

> "We collect data with regard to the characteristics given in Japanese Industrial Standard and we analyse them with histogram or control chart techniques for the purpose of studying the so-called process capability. After confirming that they are suited for Japanese Industrial Standard, we reduce them into the standards inside company, namely, Toyo Rayon Standards (TRS). Again, we evaluate the characteristics as required in the market by analysing the consumer's requirements with Pareto analysis technique and other methods and we make better standards as demanded by these market requirements."

Thus, there is general awareness that the establishment of a company standard is indispensable for the production of quality goods with minimum diversities.

There can be little doubt that the interests of both the individual manufacturer and of the whole country demand increasing efficiency in production; one of the most important elements in productivity is the development and use of standards. Rightly has said the Japanese Productivity Centre that the "principle of scientific management control lies in planning standardization and control".

IN JAPAN

Japanese Industrial Standards Committee (JISC) —The national standards in Japan are prepared by the Japanese Industrial Standards Committee (JISC). This Committee was established in the year 1949 in pursuance of the enactment of the Industrial Standardisation Law by the Japanese Government. The law stipulated the issuance of appropriate and rational standards and their diffusion. The committee consists of 240 commissioners and many technical commissioners selected from manufacturers, dealers, consumers, experts and Government officers. There are 26 divisional councils covering civil engineering, architecture, machine tools, electric materials, metals, chemicals, textiles etc. Under these divisional councils a large number of technical committees, presently about 1,600 are assigned as their auxiliary

organisations, while the general affairs of Japanese Industrial Standards Committee are being handled by the agency of industrial science and technology. At present more than 12,500 persons are engaged in the various technical committees.

The standards formulated by Japanese Industrial Standards Committee and issued in the name of Minister for International Trade and Industry become national standards i.e., Japanese Industrial Standards (JIS).

When a proposal is made for the establishment of the standard by a person or persons, such proposals are placed before the committee for their deliberation and for final decision. A preliminary draft is then prepared and examined thoroughly by a technical committee set up by Japanese Industrial Standard Committee. The final draft is subsequently reported to the division council concerned. If necessary, the draft may also be examined by the Standard Council. The president of the Japanese Industrial Standards Committee then submits the final draft to the minister. When the competent minister approves the final report then it is establishd as Japanese Industrial Standard (JIS) and it is officially announced to the public. The Japanese Industrial Standard is revised at least once in three years.

Japanese Industrial Standards numbering 5,140 had been established up to the end of year 1960, covering practically all kinds of mineral and engineering products, with the exception of medicines, chemicals for agricultural use, chemical fertilisers, silk yarn, foodstuff and agricultural products designed under agricultural and forestry goods and standards law. The latter are specified by special standards of their own. Items of fashion, luxury, taste, works of art, etc., are also excluded from Japanese Industrial Standards.

Broadly, Japanese Industrial Standards deal with the following aspects:

(a) Technical terms, symbols, etc.

(b) Kind, shape, quality properties, etc., of mineral and industrial products.

(c) Method of testing, analysis, inspection, measurement, etc.

(d) Method of design, manufacture, use, packing, etc.

Japanese Standards Association (JSA) was established in 1945 as the foundation under the government authorisation as a representative organisation on standardisation. It aims at the improvement of productivity in industry by rationalization of production and consumption through standardisation and quality control. It has its headquarters at Tokyo and branch offices at seven different places. The functions of Japanese Standards Association are:

(a) Distribution of Japanese Industrial Standards;

(b) Research and investigation of standardisation;

(c) Study of quality control, operational research and industrial engineering;

(d) Propagation work of standardisation;

(e) Propagation work of quality control—(i) holding of long and short course of quality control in Tokyo and at local centres and (ii) co-operation with the radio and television programme;

(f) Publication of periodicals and books on standardisation and quality control;

(g) Consultation work on standardisation and quality control;

(h) Ordering of foreign standards and supplying of information; and

(i) Library—complete library in Tokyo, Osaka and Nagoya with the collection of foreign standards, open to public.

Besides, Japanese Standards Association undertakes the study and assists in popularisation of quality controlling system. The Association undertakes also, for the benefit of prospective applicants for the grant of using Japanese Industrial Standards mark, and for the staff of the government officers concerned, holds series of long course of seminars extending to about 150 hours. Up to now, they have trained more than 5,000 graduates.

The total staff of Japanese Standards Association numbers about 100 of which 20 are engaged in quality control work.

Japanese Industrial Standards Certification Marking Scheme—one of the key characteristics of the Industrial Standardisation Law promulgated by the Japanese Government is the provision for the enforcement of a system to identify standard products as described in Article 19. This identification is made by a certification marking system just like the Indian Standards

Institution mark in India or the kite (BSI) mark in England. The marking system safeguards the interests of consumer by putting a special Japanese Industrial Standard mark as given below to indicate that the marked article conform to the requirements of the relevant Japanese Industrial Standard.

The government permits those manufacturers whose products conform to Japanese Industrial Standard specifications to affix the above mark as the mark of guarantee by the government and the article is called JIS marked article. For this purpose, the government announces in the official gazette (or other authoritative publication) the articles to be covered under the certification marks scheme and the manufacturers of the specified articles make application for permission to stamp their goods with the Japanese Industrial Standards mark. On the receipt of the request, the government *despatches* its official to rigorously examine the production equipment, inspection equipment, quality control methods and other technical condition of the plants of the applicant that are necessary for attaining the quality. The permission by the government to affix the mark is given only after it is satisfied that the company has introduced full fledged quality control programme and is capable of maintaining the production of goods worthy of bearing the mark. It must be mentioned in addition that much effort was necessary to introduce the new word 'Quality Control' within the provisions of law.

The granting of licence for JIS marking is not given by the Japanese Industrial Standards Committee but by the respective Ministers of the Ministry which governs the production of the particular products handled by the factory. The applicant is required to pay the government a sum of 10,000 Yen as the fee per item (counting those covered under one standard as one item) for the inspection. There is no fee for marking as such.

The improper use of the mark on the part of the manufacturers leads to the terms of imprisonment not exceeding one year or fines not exceeding one lakh Yen. Besides JIS, there are other marking systems also like Japanese Agricultural Standard (JAS) mark for food and canned food products.

Marking System in Implementation—The Government of Japan had granted by the end of December, 1960 covering 818 items of articles had issued license to 7,786 factories under the Japanese Industrial Standard Marking System. Also, the rate of increase of designed commodities and licensed factories is by 50 to 100 and 500 to 800 respectively each year.

Table 3 below gives an analysis of Japanese Industrial Standards by the number of items de-

TABLE—3

Number of Designated Commodities and Approved Factories Classified by Section

	No. of Commodities	*Approved Factories*
A Civil and Architectural Engineering	41(5)	1,143
B Mechanical Engineering	166(21)	1,266
C Electrical Engineering	100(12)	830
G Ferrous Metallurgy	42(5)	534
K Chemical Industry	163(20)	1,504
R Ceramics	42(5)	472
S Domestic Wares	69(8)	786
Z Packing only	26(3)	332
11 other sections	169(21)	918
TOTAL ...	818(100)	7,785

Note: Figures in parenthesis give only item relating to Ministry of International Trade and Industry, in percentage.

signated and the factories approved respectively by the end of December, 1960 classified according to the various sections.

Company Standards—Most of the companies in Japan have evolved their own company standards which are suitable modifications of the corresponding Japanese Industrial Standards (where available) so as to suit their own production conditions. It was found from the companies visited that the tolerances laid down in their company standards are stricter than those prescribed in the corresponding Japanese Industrial Standards. This could be explained by the fact that Japanese Industrial Standard is intended to cater to the needs of a host of companies with varying production processes and spread all over the country and hence has to be a bit more relaxed the Japanese Industrial Standard prescribes the requirements for the finished product, the companies to evolve their own standards at the various stages of processing or production so as to achieve the final quality. Depending on the end use of the product the scheme for sampling inspection at various stages is decided. The AQL generally varies from 1 to 4 per cent.

Mention may be made here of some of the companies which attach great importance to the establishment of company standards and their indispensibility for the successful working of the quality control.

In Tokyo Shibaura Electric Company (Toshiba), it was considered as a matter of routine to work according to Standard Operation Inspection Sheets and large volumes of company standards. Production is carried out in each division according to the various standards made by the Engineering Department. Works standards are then made by each work according to these standards so as to suit their own conditions, if necessary, but these works standards cannot exceed the ranges of the various characteristics stated in those standards issued by the Engineering Department. Since standardisation has been carried out in all directions at Toshiba and because operations have been conducted in this net-work of standardisation, it has been an easy task to introduce quality control.

Again, in Toyo Rayon Company, elaborate studies are conducted on the basis of quality control as to what the product specifications should be. Further revisions and developments are then made on the basis of the information collected as a result of the implementation of the specifications.

The method of setting up of the standards differs from unit to unit but the main guiding principles are as follows:

(a) To have specifications for the quality of the incoming raw material. In some companies a separate raw material inspection department has been set up.

(b) Giving specifications to sub-contractors, ensuring that the sub-contractors understand these specifications and also give them guidance and technical know-how.

(c) To have staff of the quality control department as a member of the specifications committee which is set up in majority of the units.

(d) Pilot run of the product before mass production is contemplated. This pilot run is preceded by the model of new product made according to the specifications laid.

(e) Obtain information from customers and opinion from experts on the design and appearance of the product.

(f) Analysis of the information from market on the basis of which the specifications and design of the product are modified.

The most effective means for popularisation of standardisation has been the implementation of the JIS marking system. It was stated that the JIS marked goods furnishing the quality assurance as they do, were in increasing demand by the consumers, and hence more and more companies had to take licence under the Japanese Industrial Standards marking system for stamping their goods with the JIS mark. This led to the greater use of Japanese Industrial Standards by the companies as also maintenance of standards for their products, processes and inspection.

Besides, the Government of Japan has set up the following means for the popularisation of standardisation:

(1) *Priority Given to JIS Marked Commodity*—The Japanese Government has directed the Ministries and the public enterprising organisations that while making their procurements they should give preferential treatment to commodities bearing the JIS mark.

(2) *Propagation Campaign on Nation-wide Basis*—The Government, in collaboration with the other professional bodies and associations, take special interest to extend propagation activities to people for better understanding of industrial standardisation through papers, radio, lectures, exhibitions, etc. As a result, the importance of standardisation has been gradually brought to better appreciation even to the extent of being referred to in school textbooks for the education of youth with a view to imparting knowledge of standardisation to them.

(3) *Other Promotional Activities*—To create the interest of people in the industrial standardisation, a number of prizes are awarded every year to the companies which had done meritorious work in the field of standardisation. Similarly the commissioners who have been greatly helpful in the development of standardisation are also awarded suitably. Further, the Government observes every year an 'Industrial Standardisation Month' for prize distribution and propaganda work.

Standards on Quality Control: The following Japanese Industrial Standards (JIS) relating to quality control have been established for propagating and facilitating sound development of quality control:

JIS Z 8101—1956: Glossary of Terms used in quality control.

JIS Z 9001—1956: Common Rules for Sampling Inspection (Sampling Inspection I)

JIS Z 9002—1956: Single sampling inspection by attributes based on operating characteristics (the case for the number of defectives) (Sampling Inspection II).

JIS Z 9003—1957: Single sampling inspection by Variables based on operating characteristics (the case for assuring the mean value of lots with known standard deviation; and the case for assuring the per cent defective of lots with known standard deviation) (Sampling Inspection III).

JIS Z 9004—1955: Single sampling inspection by variables based on operating characteristics (the case when either the upper or lower specification limit alone is specified with unknown standard deviation) (Sampling Inspection IV).

JIS Z 9006—1956: Single sampling inspection by attributes with screening.

JIS Z 9021—1954: Control chart methods.

JIS Z 9031—1956: Random sampling methods.

IN UNITED STATES

American Standards Association (ASA): Formed in 1918 by five leading engineering societies to coordinate the development of national standards, the American Standards Association today is an information centre on standardisation in United States. It provides organisational means for the development and approval of American Standards; it promotes the use of national standards in the United States; and it serves as the channel for cooperation in international standards work. It is a national federation of 125 technical societies and trade organisations, has more than 2000 companies as members and renders a standards coordinating and clearing house service to over 800 national, private and governmental groups.

American Standards Association believes in the voluntary development of standards according to the principle of consensus. It has both coordinative and judicial rules in standards work, not developing or writing standards itself, but only supervising the development of standards to ensure all parties concerned an equal voice in the work.

In its administrative set-up, the American Standards Association has as its main body a

Standards Council, the ultimate authority for approving American standards. In addition, it also supervises the work performed by the various boards and sectional committees, each responsible for standards work in a particular work of endeavour. Their duties include the review of standards work in their area, correlating administration and providing recommendations upon which the Standards Council acts.

The American Standards Association 'machinery' for developing American standards is geared to three methods:

(a) *Sectional Committee Method*—Under this method, standards are formulated by committees consisting of the representatives of the manufacturers, consumers and other interested parties. This method has a special advantage of affording these representatives an opportunity for blending their views on a given subject to arrive at a standard mutually acceptable to all.

(b) *Existing Standards Methods*—Under this method, an existing standard may be submitted for approval by a responsible body and may be approved by American Standards Association provided the standard is supported by the necessary consensus of those substantially concerned with it and it does not conflict with any other American standard.

(c) *General Acceptance Method*—According to this method, a general conference is called to determine the feasibility of approving as an American standard that standard which has already gained national acceptance and use. This procedure is often used for comparatively simple projects requiring little technical discussion.

Every American standard is reviewed at least once in five years, at which time it is reaffirmed, revised or withdrawn.

American Standards Association has no certification marking system as in India, Japan or UK. However, producer of goods made in conformity with an American standard are encouraged to state on their own responsibility, in advertising, promotion material, or on tag or levels, that the goods are produced in conformity with particular American standard. The inclusion in such advertising and promotion media, or on tags or levels, of information concerning the characteristics covered by the standard to define its scope is also encouraged.

About 2000 American Standards broadly covering the following types have been issued by American Standards Association so far:

1. Definitions, terminology, graphic symbols, abbreviations;
2. Standards of size, weight, volume and rating;
3. Standards on quality composition and performance for materials and products;
4. Methods of testing, analysis and rating standards on procedure safety and health.

The following standards on quality control have also been issued by the American Standards Association:

Z 1.1—1958 Guide for Quality Control.

Z 1.2—1958 Control Chart Method of analysing Data.

Z 1.3—1958 Control Chart Method of controlling quality in production.

American Standards Association also issues a monthly journal 'The Magazine of Standards' giving information with regard to standardisation activities.

American Society for Testing and Materials (ASTM): American Society for Testing and Materials promotes the knowledge of the materials and the standardisation of specifications, methods of test, recommended practices and definitions of terms relating to material. It functions through 85 main technical committees with about 2000 sub-committees which are responsible for the development of the standards and keeping them up-to-date. The work of the society is carried on through investigations and researches, the collection and publications of data on various subjects and the presentation and discussion of papers on the properties of the materials.

All the ASTM standards (numbering about 3000) are given in the '1961 Book of American Society for Testing and Materials Standards' which is divided into eleven parts. American Society for Testing and Materials has also

issued certain standards and special technical publications (STP) on quality control and mention may be made of the following:

ASTM Manual on Quality Control of Materials, STP 15-C, 1957.

Application of Statistics, STP 103, 1949.

Recommended Practice for Choice of Sampling Size to Estimate. Average Quality of a Lot or Process, American Society for Testing and Materials standards, Parts III to X, 1960.

National Bureau of Standards (NBS): Standard Materials—An important of National Bureau of Standards is the determination of constants and properties of materials. The Bureau yearly distributes 80,000 samples of standard materials to other laboratories for controlling chemical processes and maintaining apparatus and equipment accuracy. Over 600 different kinds of standards materials such as chemicals, steels, etc. are available which enable a company to check its product against the sample to see whether it is producing the materials with required properties.

Testing—The materials testing is done by the Bureau almost entirely for the purchasing, regulatory or functional responsibilities of the government agencies.

Codes and Specifications—Much of the Bureau's work on the properties of materials and methods of testing has a direct bearing on the development of engineering standards, purchase specifications, and building and safety codes. Many of the methods developed for government use are issued by the General Services Administration as Federal Standards.

Also the specifications for materials like battery cells which are drawn up by the Bureau for the Government are revised from time to time in the light of the experience gained. Everytime that the specification is revised, the requirements are made stricter but it is done with the consent of the producers. The quality control methods are often used in formulating these specifications or their revisions.

Besides, the Bureau assists the other standardising bodies, like American Standards Association and American Society for Testing and Materials in evolving the national standards. Through membership on numerous committees of these bodies, the Bureau often helps to secure agreement on recommended practices by providing methods of test, basic data on properties of materials, and information on possible measurement of accuracy.

Company Standardization: The company standards have played a valuable part in the development of the industrial economy of America. Mention may be made here of the standardisation activities in some of the companies.

Eastman Kodak Company—A unique and commendable feature was observed in the Kodak company in respect of evolving design specifications for various parts and products. The proposed specifications which are drawn up by the engineering department are submitted to the quality control department for their consideration and approval before any manufacturing can take place. The quality control department conducts tests on prototype samples or working models prepared according to the proposed specifications, determines whether or not it will be practicable to go into production on the new model and then only accords its approval with modifications, if any. The regular production starts only after the proposal has been approved by the quality control department.

The company follows the American Standards wherever they are available; with regard to the remaining parts and products, they have their own standards. The statistical methods have been used in fixing the tolerances on assemblies in certain cases. Also, the information collected from the processes is fed back to the engineering department with a view to revising the specification, if necessary. Besides, the quality control department feels and endeavours that the reliability of a product, such as the number of rolls filled, the number of hours run should be specified in the design specifications.

Bausch and Lomb Incorporated — Great importance is attached by the company to the standardisation of products, processes and inspection procedures so as to provide for ful' customer satisfaction at an economic level.

The design specifications, which prescribe the requirements for the different products, are

formulated by the engineering department who are primarily responsible for them. However, the statistical information collected by the quality assurance department with regard to the process capability. performance, etc. are fed back to the engineering department with a view to reviewing the specifications and determining the quality requirements of future products.

In a similar manner the concerned departments collaborate to evolve objective inspection procedures for determining the conformity (or otherwise) of the manufactured products to the specified requirements. Furthermore, standard formats have been established for the purpose of unifying the presentation of different inspection procedures. These formats carry all information and instructions necessary to reduce the time devoted by the supervisory personnel to interpreting the procedures or instructing the operators as well as to eliminating ambiguity in the interpretation of specifications and/or procedures.

In case of material specifications, it may be mentioned, the quality is well defined where it involves the measurement of dimensional and performance characteristics and hence is amenable to control, but not so in case of visual characteristics like cosmetic and optical defects. Accordingly it becomes essential to evolve objective procedures for the inspection of such characteristics. The company has succeeded in developing visual standards for the gradation of scratches, digs, etc. in the increasing order of severity.

It may be mentioned that the attainment of production objectives and quality control practices and procedures are reviewed from time to time so as to give maximum quality assurance at minimum cost. Corrective measures are immediately taken in case the products fail to conform to the specification requirements.

It is also interesting to observe that the company, during its existence of over a century, has carried out several simplification programmes resulting from the standardisation of the products and components. For example, the screw thread sizes have been reduced from 1,500 to 850, the 30 different types of a product were cut down to 4.

Western Electric Company—The company has a Standards and Reliability Group which is primarily concerned with problems of a consultative nature, reliability and life tests. The specifications and the standards are laid down by the Bell Telephone Laboratories in New York. For many characteristics this is done on the basis of pilot-scale production and hence the data may not be large enough to be valid. Many instances were cited, where it became necessary to modify the specifications because they were found to be too tight or too loose for the process to cope with. The quality assurance department which reports to the New York office ensures on the basis of a small random sample whether the product meets the specifications. Any deviations from the specifications are not identified as a defect but classified into four categories according to the seriousness of how it will affect the customer. The Standards Organisation reports on maintenance not only of the process but of the testing equipment also for which the periodicity of calibration is laid out.

Radio Corporation of America—Approving specifications and changes, determining product conformance to specifications, and ensuring that the final product is as specified, all come under the responsibilities of the quality control department. There is a product release committee with representatives from quality control, sales and manufacturing departments which makes a decision whether it is possible to ship a product in the face of a particular failure or slight deviation from the standards. If it is agreed, all sign the agreement and the customer acceptance is also taken. Details of the method of inspection, tolerances, etc., are given for all operations in writing. The company's own specifications are established on the basis of data suitably collected and are revised as the quality improves. However, in case of military specifications, when the data show the desirability of the modification of the specifications, the military is suitably advised to this effect.

IN UNITED KINGDOM

The British Standards Institution has been greatly responsible for the development of standardisation in United Kingdom. Set up in 1901, it was the first unit of its kind to be established anywhere in the world. Besides its pioneering work in the preparation and promul-

gation of British standards at the national level, it has been a source of inspiration to other sister standards organisations in different countries. Its objects and purposes were set out in the Royal Charter of 1929 in the following terms:

(a) To co-ordinate the efforts of producers and users for the improvement, standardisation and simplification of engineering and industrial materials so as to simplify production and distribution, and to eliminate the national waste of time and material involved in the production of an unnecessary variety of patterns and sizes of articles for one and the same purpose.

(b) To set up standards of quality and dimensions, and prepare and promote the general adoption of British Standard specifications and schedules in connection therewith and from time to time to revise, alter and amend such specifications and schedules as experience and circumstances may require.

(c) To register, in the name of the Institution, marks of all descriptions, and to prove and affix or license the affixing of such marks or other proof, letter, name, description or device.

(d) To take such action as may appear desirable or necessary to protect the objects or interests of the Institution.

The responsibility for BSI's policies, as a whole, is vested in the General Council while the day-to-day control in an Executive Committee and the financial matters in a Finance Committee. There are four Division Councils, namely, Building, Engineering, Chemical and Textile, and a Council for Codes of Practice. The preparation of standards is carried out by the technical committees consisting of representatives of bodies concerned with the particular work referred to them. Each of these committees (with a few exceptions) reports to the appropriate Industrial Standards Committee which is responsible for authorising the enunciation of any standards project, for approving the final draft before issue and for deciding the priorities of the various projects authorised.

Besides, there are a number of Advisory Committees, such as the Export Panel, the Advisory Council on Standards for consumer goods, etc., which report direct to the General Council but are not responsible for the technical content in the standards.

The British Standards Institution is financed by a government grant, the subscriptions from its members and by the sale of standards and other publications. Though financially assisted by the government, it is not under the government control and remains an independent body so as to secure the agreement of all concerned.

Preparation of Standard: Proposals for the preparation of standards may come from any quarter, from the manufacturers of a product or its users, from government departments or from BSI committees already working on standards. Before work is started on any proposal, it is ascertained clear that there is support for it from responsible bodies concerned.

In the preparation of standards, the British Standards Institution staff is responsible for the detailed drafting and editorial work and for securing any necessary co-ordination with standards work in related fields. It is also responsible for seeing that any relevant overseas standards or international work are brought to the attention to the technical committee so that full account may be taken of these both before consideration.

When initial drafting of standards has been completed, it is circulated as a 'draft for comment' to all interests concerned. When comments are received, they are considered by the responsible committee and adopted, modified or rejected according to the consensus of informed committee opinion. A draft, as finally agreed by the technical committee, is then submitted to the relevant Industrial Standards Committee for approval.

There are over 3,000 committees and subcommittees in existence with about 17,000 committee members. About 3,400 British standards on dimensions, performance, quality, method of tests, terms and symbols and codes of practice have been published. The following standards on Quality Control have also been issued by the British Standards Institution with a view to disseminating the knowledge of Quality Control in industries:

B.S. 600:1935	Application of statistical methods to industrial standardisation and Quality Control.

B.S. 1313:1947 Fraction-defective charts for Quality Control.

B.S. 2635:1955 Drafting specifications based on limiting the number of defectives permitted in small samples.

B.S. 2564:1955 Control chart technique when manufacturing to a specification, with special reference to articles machined to dimensional tolerances.

Certification Marking: The British Standards Institution operates a Certification Marking Scheme under which the manufacturers are granted licences to stamp their goods to use the BSI (kite) mark.

The purpose of marking is to provide an independent assurance, reinforcing the statement by the manufacturer that goods comply with the relevant British Standard. The permission to use the Mark is granted only after the manufacturer and the BSI have agreed on a system of inspection on sampling and testing appropriate to the particular product. At present the products of nearly 100 industries bear the kite mark. The marked products include industrial safety boots, gloves, hats, motor-cyclist's protective hats, safety glass for cars, transformers, etc.

Company Standardization: The overall development of company standardization in UK did not appear to be very marked. However, mention may be made here of the General Electric Co., where quite useful work has been done in respect of developing the company specifications on the basis of Quality Control principles and reveiwing them from time to time in the light of the experience gained.

7 : Training in Quality Control

TRAINING in the field of Quality Control has been given a prominent consideration in all the countries and factories visited abroad. Apart from the staff in the Quality Control Department, personnel in various categories—top management, technicians and workers—have been given an undestanding of the theory and practice of the quality control procedures in most of the factories visited abroad.

A special point may be made in the case of industries in Japan: "Prior to World War II, if one had taken an international public opinion poll on the product quality reputation of the various industrialized countries, the rankings would very likely have shown Switzerland at the top, followed by various other Western countries, and with Japan at the bottom. Now, two decades later, Japan has climbed that ranking, rung by rung, until it has arrived at a position of respect in most product categories, and to a position of leadership in some." (J. M. Juran, *Industrial Quality Control*, March 1961.) Training activities have played no small part in this outstanding achievement in Japan. In Japan quality control is considered as a revolution in the ideas of management and it is essential for good management control. One of the main reasons for the rapid progress of quality control in Japan is due to the great care with which the training programmes have been planned at different levels. Education in quality control is aimed at 'converting' the way of thinking of all the employees including presidents of companies.

The United States of America has played a leading role in the development of philosophy and techniques of quality control. In fact it may be said that the experience of the workers in the field of quality control has been a great source of inspiration in the development of quality control movement outside USA. In the United States of America during the last 15 years the quality control techniques are being used on a very wide scale. These applications have been made possible because of the introduction of clinics, conferences and training courses on a large scale throughout the United States.

In-Plant Training

In Japan, a number of companies organise training in quality control for their own employees. Quality Control engineers who are graduates in the basic course in quality control give lectures in the factory training courses. Some of them have brought out textbooks and training manuals in quality control. Training courses are organised in the companies at different levels—operatives, supervisors, inspectors, shop managers, engineers, etc. It is interesting to note that some of the companies have organised training in quality control for chiefs of clerical departments and clerks.

Training courses organised for operators do not generally extend beyond one month. In this course practical problems are discussed and 'thumb rule' principles are given. Emphasis is given on the following :

(a) how to draw a random sample;

(b) drawing of control charts;

(c) standard sampling inspection plans; and

(d) drawing of graphs and use of simple statistical tables.

The training programme of some of the industries in Japan is discussed in the following sections.

The training programme of the Tokyo Shibaura Electric Co., Japan, is given below as described by the company:

"The first problem faced in carrying out quality control is how well the people concerned with it understand quality control. Therefore, it is impossible to carry out an effective qua-

lity control programme if we disregard quality control education and training.

"Education and training has been considered to be very important at Toshiba and we issued a Quality Control Training Policy Statement in 1957 and set the basic viewpoint concerning quality control training at Toshiba. In carrying this out, each division has its own programme tailored to their individual conditions."

According to the Quality Control Training Policy Statement, the programme is divided into the following three classes, (1) shop supervisors, (2) department managers and superintendents, and (3) quality control engineers. It is prescribed as a general rule in the Statement that the conference method will be used for shop supervisors and managers and superintendents, while seminars will be used for quality control engineers.

The training manual for shop supervisors (foremen) have been made individually by each division to bring out the special characteristics of each division. For instance, statistical methods are explained rather in detail in the Lamp and Tube Division, while the prevention of errors are emphasised in the Apparatus Division. The education and training of this class has made rapid progress and except for special cases has been nearly completed.

The conference method is also adopted for the education of department managers and superintendents using a suitable textbook. The state of progress differs according to the divisions, and some have made a rather rapid progress while some are slow.

A rather high grade lecture course centred mainly on the design of experiments is being given to quality control engineers.

Also, lecture courses on quality control techniques are being given to engineers in the shop, research laboratory, and engineering, and is being of great help in carrying out quality control.

The quality control training at Yawata Iron and Steel Co. Ltd., Japan is given below as described by the Company:

"Any company regardless of size or organisation must teach its employees about the company and its operation. This is especially true in a large line-staff organisation where, because of the specification of function, few employees can fully appreciate their own place in the complete works or the position and function of other departments."

The orientation and training programme at Yawata is carried out by the Training Department. The programme is extensive and includes, besides Quality Control, other subjects like general theory of iron and steel making, production and other operation techniques, and foreign languages. There are courses designed to meet the needs of new employees, key personnel, foremen and maintenance personnel.

Lectures are given to increase appreciation of quality control, the use of control charts, statistical methods and theory, sampling, experimental methods, operations research, etc. The programme is well integrated and instruction is tailored to meet the needs and abilities of the different levels of students. Training programmes now contain from 100 to 150 hours of instruction. Lecturers are as a rule senior staff members; however, when deemed necessary, qualified instructors from outside the company are hired.

The quality control education programme of Fuji Photo Films Co., Ltd., Japan is described in Table 4. (*Quality Control in Japan*, ibid).

The courses (at Fuji Photo Films Co.,) are held in such a way graduates from A course are raised to B and C courses and graduates from B and C courses enter D and E courses. The courses are all held about 3 hours a week.

Most of the factories in the United States of America have in-plant programmes. The Team members saw many training manuals developed in the plants, particularly in Bristol-Myers, Western Electric Co., Singer Manufacturing Co., and Radio Corporation of America. The factories which do not have training facilities in their own plants send their personnel to outside courses.

The in-plant training programme of the Western Electric Co., Allentown Works, USA, is summarised in Table 5.

TABLE—4

The QC Education Courses in 1957 (Fuji Photo Films Co. Ltd.)

Title of Course	*Hours Participants*	*Persons Educated*	*Contents*
A. Introduction to QC	24 Hours 165	Chiefs of Clerical Departments and Section	Control, organisation, quality, control charts, statistical methods, inspection.
		Member of control departments	—Do—
B. Control Charts	36 Hours 33	Engineers, Shop managers	Job specification and functions of QC system, how to read control charts, how to use it, analysis control of process.
C. Statistical Methods	60 Hours 53	Engineers	Distribution of statistics, estimation test of significance, correlation, regression, introduction to experimental design.
D. Design of Experiments	90 Hours 33	Engineers	Analysis of data, theory of analysis, planning of experiments mainly on 2″ type, 3″ type, and table orthogonal arrays.
E. Sampling Inspection and Sampling Technique	30 Hours 52	Engineers	Design and operation of inspection, details of sampling inspection, Method of sampling.

TABLE—5

Allentown Statistical Quality Control Training Programme

Title of Course	*Hours*	*Persons Educated*	*Participants*
Management	10	Staff	15
Basic	18	Supervisors and Engineers	729
Basic	10	Associate Engineers and Technical Assistants	65
Refresher	3	Supervisors and Engineers	280
Short Basic	6	Key Shop Personnel	432
Sampling Inspection	10	Supervisors and Inspectors	70
Design of Experiments	21	Supervisors and Engineers	308
2 Weeks at Universities	80	Engineers	20

The details of the in-plant training programme in quality control at Joseph Lucas Ltd., UK, are given below. The selection of participants is in the hands of the departmental heads.

SESSION I

AN INTRODUCTION TO QUALITY CONTROL

Aim of Course—History—Development and Wartime Application—American Success—Lucas Application—Facts and Targets —Defect Prevention—Difference between Quality Control and Inspection—Measurement of Progress—The Effect of Quality Control on—1. Direct operators, 2. Indirect operators—Material Shortage—Programme of Introduction— Co-operation—Pitfalls —Flexibility.

AIDS—A Quality Control Chart, Lucas Number Defective Chart, Photographs, Slogan, Quality Index Chart.

SESSION II

THE BASIC PRINCIPLES OF QUALITY CONTROL

Review of Session I.—Definition —Distribution Picture—Pattern Average—Action Lines—Causes of Defective Work—Patrol Viewing.

AIDS—from Session I. and Mustard Seed Demonstration, Road Diagram.

SESSION III

CHARTS

Review Charts—Average and Range Chart—Calculation of Average—Calculation of Range —Specification Limits.

Fraction Defective Chart—Demonstration — Conclusion—The Average—Action Lines—Missing Lower Action Line.

AIDS—from previous sessions and Average and Range Chart, Micrometer, Fraction Defective Chart Marbles Demonstration Set, Go, No Go Gauge.

SESSION IV

CHARTS AND SAMPLING

Review—Lucas Number Defective Chart—Defects per Unit Chart—Combinations of Charts —Quality Colour—Recording Results — Sampling — Double Sampling — Application to Bought Out Inspection—100% Inspection—200% Inspection.

AIDS—from previous sessions and Lucas Number Defective Chart, Defective per Unit Chart, Combined Quality Control Chart, Quality Control Chart Stand, Sampling Diagram, Bought Out Inspection, T.W.I. Sheet, Racing Magneto Inspection.

SESSION V

REVIEW

Training manuals for trainees and trainers have been developed at Joseph Lucas Limited.

Outside Training

Education in quality control in Japan has covered a very wide circle since 1947. The total number of participants in the lecture courses, excluding those organised within factories, is more than 38,000. Those who have received quality control education within their respective firms or through radio broadcasts probably amount to more than 2 millions.

Most of the lecture courses are sponsored by scientific and technical organisations. The Japanese Union of Scientists and Engineers (JUSE) and the Japanese Standards Association are the main centres of Quality Control education. University professors have taken a leading part in the development and training activities.

A number of short-term lecture courses (2 to 5 days) are held throughout Japan. These are

elementary courses aimed at spreading the general philosophy of Quality Control techniques. On the other hand a fairly detailed course spread over 6 months (2 days in a week) is organised regularly to educate Quality Control engineers.

Quality Control Training Courses are also organised within many enterprises. In some companies training in Quality Control has converted all the employees including the presidents. Many companies have prepared textbooks, movie and slide films for the education of their employees in Quality Control.

Universities have started giving Quality Control education to engineering students.

Training courses in Quality Control are also organised exclusively for the departmental heads and sections of factories. These courses are spread over four months with 3 to 4 sessions in a month. More than 850 participants from 150 firms have attended this course.

Short-term appreciation courses are organised for management. So far 20 such courses have been organised. Details of techniques are avoided. The main emphasis is on the organisational and economic aspects of Quality Control.

Training in Quality Control is also organised for the national and local government officials. The Ministry of International Trade and Industry has taken special interest in the training of officials concerned with the Japanese Industrial Standard.

The training courses give stress on Quality Control as an integral part of management control. In each course however, lectures on Statistical methods occupy major part of the time. The training activities mentioned above have achieved good results in the promotion of Quality Control in Japan and in the re-education of engineers, office-workers and foremen in various enterprises.

The summary of Quality Control education held by outside organisations since 1949 upto October 1957 is given in Tables 6 and 7. These however do not include courses held by organisations other than mentioned in table 7 or minor lecture courses of less than 10 hours.

TABLE—6

The Annual Number of Participants in Quality Control Courses

Year	*10-24 hours*	*25-49 hours*	*50-99 hours*	*100-149 hours*	*150 hours or more*	*Total*
1949 ...	500(2)	—	—	—	39(1)	539 3)
1950 ...	300(1)	1,024(4)	37(1)	—	70(1)	1,431(7)
1951 ...	2,312(9)	1,032(6)	203(4)	221(4)	205(3)	3,973(26)
1952 ...	2,410(10)	232(3)	133(3)	128(4)	328(5)	3,231(25)
1953 ...	2,838(14)	1,179(7)	235(5)	178(3)	227(3)	4,657(32)
1954 ...	3,668(30)	1,722(9)	742(13)	257(5)	575(7)	6,964(64)
1955 ...	1,989(18)	2,107(13)	779(18)	282(5)	504(6)	5,661(60)
1956 ...	2,963(27)	1,158(7)	805(13)	542(9)	811(9)	6,279(65)
1957 (to October) ...	2,372(27)	1,224(10)	516(7)	565(7)	495(5)	5,172(52)
TOTAL ...	19,352(134)	9,678(59)	3,450(64)	2,178(37)	3,254(40)	37,907(334)

NOTE: The numerals within parentheses show the number of courses held.
Each year indicates a calendar year, excepting 1957 which is totalled until October.

TABLE—7

Contents of the Lectures in the Quality Control Basic Course (JUSE)

Subjects	*No. of hours*	*Contents*
(1) QC admission . .	18 hours	Functions of QC, system, diagnosis of quality, diagnosis of processes, management of QC, assurance of quality, control in large-variety-small-quantity production.
(2) Control Charts . .	30 hours	How to make control charts, how to read them, process analysis, process control, special process control.
(3) Statistical method ...	30 hours	Theory of errors, random sampling, multi-stage distribution of statistics, test of significance, estimation, correlation, regression, binomial probability paper, design of experiments, covariance analysis, analysis of past data, time series.
	15 hours	Exercises.
(4) Sampling ...	24 hours	Theory of errors, random sampling, multi-stage sampling, stratified sampling, cluster sampling; sampling of liquids, solids, and ores; models: design of sampling and experimentation.
(5) Sampling Inspection ...	27 hours	Sampling inspection by attributes and variables; theory and practice of single; doubel, multiple and sequential sampling inspection; sampling inspection with screening, with adjustment, and for continuous production.
(6) Statistical theory ...	39 hours	Theory of probability, theory of sampling, stochastic process.
(7) Exercises using actual examples ...	18 hours	
TOTAL ...	201 hours	

Long-term training courses to educate professional Quality Control engineers are held by Japanese Union of Scientists and Engineers, Japanese Standards Association, and the central industries association. The courses conducted by Japanese Union of Scientists Engineers are described below.

Basic course in Quality Control (Held by JUSE)

This course was started in 1949. So far 2450 participants have attended the basic courses. Majority of the persons working in Quality Control Sections in factories are graduates of these courses. The duration of the course is 6 months and consists of 220 hours of lecture and practical exercises. The participants attend classes for one week in a month and return to their respective firms in the other weeks to do their work and to prepare and review their lessons and do home-works. Each participant under the guidance of his lecturers takes up practical problems in his field to learn how to make practical applications and achieve practical results.

The syllabus followed in the basic course in Quality Control is given in Table 8. It indicates that Statistics is taught at a fairly advanced levels to the engineers.

TABLE—8

Contents of the Course on Design of Experiments (JUSE)

Subjects	*Hours*	*Contents*
(1) Analysis of data	Lecture: 30 hours	One, two- and three-way layouts, Latin squares, Ggraeco-Latin squares, hyper squares, confounded designs quasi-Latin squares, split-plot designs, tractional experiments, balanced incomplete blocks, lattice designs, lattice squares, Youden squares, covariance analysis, associated data, 2′ type 3′ type, attribute data, past data.
(2) Theory of analysis	Lecture: 30 hours Exercise: 6 hours	Theory of linear estimation, theory of testing, expected value of the variance, subdivision of the sum of squares, analysis of confounded designs, layout of designs using orthogonal arrays, orthogonal polynomials, weighing problem.
(3) Planning of experiments	Lectures: 36 hours	Organization and management of experiments, factory experiments, principles of experimental design, methods to increase the precision of experiments, relative efficiency of designs, models how to select factors, how to determine the number of levels, error of the second kind, use of punch cards in making layouts, how to conduct sequential experiments, designs for determining optimum conditions.
(4) Case studies ..	24 hours	Problems concerning standards and specifications in the mechanical industry, examples in the electric machinery industry, examples in the textiles industry, examples in the metal industry, examples in the chemical industry, examples of errors made in experiments, other examples.
(5) Special lectures ...	12 hours	Sampling experiments, examples of the application of experimental design to market research, experimental design for inspection, how to conduct and analysis sensory tests.
(6) Case studies and discussions ...	21 hours	Discussions of case studies made by participants and others.
(7) Preliminary lectures	6 hours	Introduction to statistical methods.
TOTAL ...	165 hours	

The design of experiments (Held by JUSE) Statistically designed experiments have found wide application in Quality Control work in Japan. Training in Design of Experiments is organised for graduates of the basic course. The duration of this training is 8 months. Lectures are delivered 4 to 5 days in a month. So far 400 participants have received training. The contents of the lecture for this course is given in Table 8.

Education in quality control has received great attention in USA. Annually about 850 programmes are conducted (by all sections of the American Society for Quality Control—See Chapter 8 for details regarding American Society for Quality Control) including training courses, conferences, talks, symposia, etc. The training courses are conducted by universities, technical and scientific organisations and consultants. The duration of the training courses is short and ranges from 8 days to 21 days. The courses are

specialised but not limited and are directed towards different levels. Courses are organised throughout the year and covers the whole country. Workshop seminars which include a demonstration study is a special feature of the American training programmes.

There does not appear to be any uniform system for the training of professionals in Quality Control. The Team had an opportunity to visit the Statistical Centre of the Rutgers University which offers evening courses in Quality Control. This course gives a fairly advanced statistical background to engineers to enable them to practise Quality Control. The University offers Master's Degree and Ph.D. in Quality Control. Many of the factories around that area have taken good advantage of the opportunities provided by the University. Persons trained through these courses have been able to establish good Quality Control system in the factories. This system has provided an opportunity of direct contact between the University professors and engineers from industry. Quality Control practitioners in industry also give lectures in these courses. The Rutgers University programme in Applied and Mathematical Statistics was given initial support, both financially and advisory by some twenty industries in that area. The Team was not able to ascertain whether similar training programmes were being organised at any other universities. This, however, makes one point fairly clear, i.e., it is essential to teach statistical methods at a fairly advanced level to the engineers if they are to be made professionals in Quality Control.

The British Productivity Council organises seminars and courses on Quality Control as a tool for production. Participants are drawn from various industries. The following topics are discussed:

(a) Survey of control of Quality;

(b) Frequency Distributions;

(c) Sampling from a normal Distribution;

(d) Control Charts for Measurements;

(e) Quality Control by Number Defectives;

(f) Sampling Inspection;

(g) Sampling Inspection Tables;

(h) Case Studies; and

(i) Process Investigations.

Radio & TV Programmes

Quality Control education over radio in Japan began in July 1956. The Nippon Shortwave Broadcasting Co., (NSB) held a three-month course (15 minutes per week-day) 7 times, the contents of which were:

(a) Prevention of Defective (Twice);

(b) Design of Quality;

(c) Cost-cutting; and

(d) Standardization.

During the summer of 1957 NHK broadcast an introductory course called MANAGEMENT AND QUALITY CONTROL for 7 weeks (15 minutes per week-day). About 1,00;000 copies of this text have been distributed.

A course in probability and statistics was presented for half an hour each day during week-days for five months over the NBC TV network, USA.

The above TV course focussed attention on the mathematical theory and applications of this theory to statistical inference. The course included counting methods, sets, normal distributions, binomial distribution, distributions of random variables, central limit theorems, sampling theory, confidence limits hypothesis testing, use of prior information, and sums of independent random variables.

It is estimated that the above TV course was watched by about 95,000 persons. It is also said that 66,000 copies of the recommended book were sold.

8 : Promotional Activities

PROMOTIONAL activities undertaken in the field of quality control in Japan, the USA and the UK are discussed in the following section. Some aspects of promotional activities have already been presented in earlier sections. These aspects are briefly presented alongwith some other aspects and the structure, organisations and functions of American Society for Quality Control (ASQC) are discussed in detail.

IN JAPAN

Japanese industries which were keenly aware of the need for export of uniform quality goods in a competitive markets and to reduce their cost of production were very quick to grasp the utility of Quality Control techniques. Industrial establishments, Research Associations, Technical Societies and the Government of Japan all collaborated to create a suitable climate for ushering a new era of 'Quality of Control' in Japan.

A brief summary of the promotional activities undertaken is given below:

(a) The Japanese Union of Scientific and Engineering, Japanese Standard Association and the University Professors have played an important role in the promotion and development of Quality Control in Japan. The Industrial Standardisation Law enacted in July 1949 makes the application of Quality Control a prerequisite for obtaining the authorisation of Japanese Industrial Standard mark. This had a great bearing on many organisations taking to the use of Quality Control Techniques.

(b) In addition to the local efforts they invited specialists from abroad. W. E. Deming and J. M. Juran, both from USA, lectured extensively on Statistical Quality Control and Management of Quality Control.

(c) There are many independent inspection laboratories to certify goods for export.

(d) The award of Deming Prize for individuals and industries has created competitive stimulation amongst industries and individuals for doing Quality Control work. Industries and individuals are proud of this award.

(e) The system of giving honour by the Minister of Industrial Trade and Industry to factories with outstanding performance in the application of Quality Control and standardization has been another factor in the popularisation of quality control.

(f) Since 1960 a month is earmarked as "National Quality Month" in Japan. During this month special conferences are conducted in Quality Control all over Japan. A 'Q' flag flies over all the industries all over Japan.

(g) Consumers reaction to quality is solicited within Japan by the press and radio.

(h) Japanese quality is propagandised abroad There is a trade centre at Osaka called Osaka International Trade Centre wherein the products manufactured in Japan alongwith products from other countries are exhibited.

(i) Quality Control posters both inside and outside industry are used extensively to stimulate thinking on 'Quality'.

(j) Promotional activities are laying stress on the use of Quality Control techniques in the small scale industries. Quality Control in small scale enterprises with less than 300 employees have become very active in the past three years. There is an instance of a company that is carrying on Quality Control with only fifteen employees, including the president.

(k) Quality Control in Japan is not limited to production problems only. In concept, it

is applicable to all activities in any organisation. Total Quality Control is the aim of setting up Quality Control Section in factories. Efforts are being made to spread the application of Operation Research Techniques. At the national level, the main aim of Quality Control is the optimum utilisation of national resources.

(l) It is interesting to note that almost all technical associations have taken keen interest and actively participated in the propagation of Quality Control techniques.

(m) Considerable number of books, journals and pamphlets on Quality Control are published in Japan.

IN USA

The American Society for Quality Control (ASQC) is the main centre of Quality Control movement in the United States of America. A brief description of the organisation is presented in the following sections.

The American Society for Quality Control was established in 1946. 13 individual local organisations merged together to form the American Society for Quality Control. The society has now about 14,000 members. It is a non-profit-making educational and scientific society. Its purpose is to create, promote and stimulate interest in the advancement and diffusion of the science of Quality Control and of its application to industrial processes, among management and technical persons working in the industrial field. It gives a platform to technical and research workers of different domains of science to exchange their views. The main activities of the society may be stated as:

(a) Organising training courses for all levels of technical personnel and management;

(b) Holding seminars and annual conferences on specialised topics; and

(c) Publishing journals on methods of quality control and industrial problems.

The society has 115 sections throughout the country. The society conducts about 850 programmes annually through its various sections.

Certain specialised industrial fields have established divisions within American Society for Quality Control by means of specialised programmes at national meetings and conferences. The divisions focus the attention of the society's membership on technical problems and developments in the fields they represent. In addition to the present Divisions, there are specialised industry technical committees. Presently these committees cover these industries and fields: brewing, manufacturing and assembly, metals, vendor-vendee, operations research, and applied methodology. American Society for Quality Control divisions function in the following areas.

(a) Administrative Applications

(b) Aircraft and Missile

(c) Automotive

(d) Chemical

(e) Electronics

(f) Food and Allied Industries

(g) Textile and Needle Trades.

INDUSTRIAL QUALITY CONTROL, published monthly is the official Journal of the Society. Widely respected for its technical content, each issue contains a wealth of valuable information covering pertinent news in the field of Quality Control, activities of the society and its local sections, plus practical, technical articles of importance. The society in association with the American Statistical Association brings out a quarterly entitled TECHNOMETRIES, which is intended to serve the researcher in the physical, chemical and engineering sciences.

Another area of service by the society is professional development for which five committees work. The professional Development committee is studying delineation of all important Quality Control work elements, and a plan for examining, licensing, and for certifying those who qualify as Professional Quality Control Engineers. This programme will help both college graduate and non-graduate personnel to secure appropriate training, and valuable recognition and identification in their profession.

For outstanding work in the field of Quality Control the society awards every year a number of medals such as Shewhart Medal, Edwards Medal, Brumbaugh Medal, etc.

The industries approach the society for help

and guidance for solving their problems on Quality Control. It refers the matter to the appropriate division and the solution is forwarded to the industry in due course.

IN UK

The British Productivity Council constituted a British Productivity Council Quality Control Committee in 1955, as a national group for the promotion of Quality Control. The formation of the European Organisation for Quality Control (EOQC) gave a new impetus for the Quality Control movement in UK and other countries in the continent. European Organisation for Quality Control holds regular conferences, publishes a journal and helps in the exchange of information between the countries.

In July 1961, the National Council of Quality Control and Reliability was formed. It is proposed to organise residential training courses for teachers of quality control. The European Organisation for Quality Control has also formed a glossary committee for the standardisation of terms used in quality control. The European Organisation for Quality Control (EOQC) coordinates the activities of the national Quality Control organisations of various European countries. It helps in the exchange of information and experience gathered in different countries.

9 : Quality Control in India

BEFORE studying Quality Control practices and procedures abroad, the Team members visited a number of industries and organisations connected with Quality Control work in several parts of the country.

The concept of Quality Control, the Team members had before study at home and abroad, was that of Total Quality Control (for an original exposition see Appendix C) as emphasised by A. V. Feigenbaum of General Electric Company, USA.

The summary of conclusions on the observations made by the Team, given below, summarises the status of Quality Control in Indian industries.

(a) Barring a few cases the managements have not fully recognised the scope and utility of modern quality control programme. Its benefits in improving quality, increasing production, reducing cost in production and distribution have not been appreciated, in the sense that no effective Quality Control Programme was evident.

(b) It was also evident that top production personnel and supervisors have not evinced sufficient interest in quality control activities.

(c) Inspection function has been given its due importance in most of the industries. However, effective use of inspection information was not evident in most cases.

(d) Statistical Quality Control techniques are not being used to any appreciable extent in the Indian industries.

(e) It was noted that in most factories visited there were no personnel to deal with the statistical aspect of the Quality Control problems effectively.

(f) It was apparent that those production personnel who had received short training in Quality Control were not confident in the application of Statistical Quality Control techniques by themselves. However, they were appreciative of the techniques and procedures and were ready to give co-operation to the Quality Control Programme.

(g) It was observed that whatever the services of consultants in the field of Quality Control were utilised, there were some tangible results and the need for Quality Control Programme was felt.

(h) It was also noted that the quality control work, (consultation, training and promotion) at present, is being done mostly by persons who have statistical training.

(i) It was also noted that there was no publicity material available on the subject apart from training manuals and Indian Standards Institution's publications.

(j) To sum up, it appears reasonable to state that the full-fledged quality control activities are still in initial stages in India. There is a growing awareness on the need for 'Quality' in industry.

10 : Summary of Observations

MANAGEMENT POLICY

A remarkable feature of the industries visited in Japan, the USA and the UK was the seriousness with which the top management had come to regard Quality Control as an overall management function. The success of Quality Control can be attributed to this direct interest taken by the management. The top management's objectives towards Quality Control activity were well-defined and directives were issued for the implementation of the objectives. These were issued in the form of policy statements.

The management was constantly endeavouring to improve product quality and reduce costs. To this end the recommendations which were feasible or practicable were immediately implemented.

ORGANISATIONS & FUNCTIONS

In all the factories visited abroad a separate department for Quality Control existed. In most of the factories, the inspection department was merged with Quality Control or Quality Assurance department. The head of the department reported directly to the management.

In the industries in Japan, Quality Control activities were directed and coordinated by a committee. In small factories in Japan the inspection department performed the Quality Control activities under the overall guidance of the quality control committee presided over by the plant manager.

In some of the factories visited in the USA a separate statistical services section existed. In some factories this section was considered as a service section to the whole plant and was not directly under Quality Control department. In some factories it was a separate section under the Quality Control department. In all the factories the Statistical Quality Control function was considered as quality control engineering work.

Quality Control functions in many factories, apart from its applications in actual production, also extended to such activities as research and development of new products, market research, claim handling, administrative applications and training.

EVALUATION & BENEFITS

In every factory the management stated clearly that the benefits they had achieved from quality control were improvement in quality, increase in production, reduction in costs and reduced customer complaints. The evaluation of Quality Control work was not attempted in all the factories. The reason given for not having an evaluation programme was that the management considered Quality Control as an essential function and there was no doubt as to its usefulness. There were, however, some factories where there were good schemes for evaluation of Quality Control.

PERSONNEL

At a meeting held in Japan with the experts in Quality Control, they were of the view that a person with engineering background and with necessary training in statistical methods would be suitable for Quality Control work.

The technical and managerial aspects of Quality Control work was carried out by Quality Control Engineers in USA. Under this category were also included persons with academic qualifications in statistical methods.

TOOLS & TECHNIQUES

Inspection plays an important role in Quality Control activity. The amount of inspection, type, place and standard of acceptance were all laid down in comprehensive inspection manuals issued by the Quality Control manager. It was noted that in most of the factories visited statistical sampling plans were in use in receiving and in

process inspection. The inspection data were being utilised effectively for controlling the processes and statistical analysis of data were invariably done.

Modern techniques of inspection had been developed for increased efficiency at reduced cost of inspection; automatic gauging and sorting procedures, X-rays and other non-destructive methods have been developed; process control instrumentation with feedback devices had been successfully implemented. In most of the factories there were many instances where the company had developed its own inspection equipment for special situation either independently or in collaboration with others. Inspection gauges and test equipment were maintained with specified accuracy and periodic calibration was made against known sub-standards and master standards. In one of the factories in USA "mobile calibration van" was being put to use.

Some special points noted during the tour regarding inspection and metrology were: the development of fibre optics, quality rig testing, simulating service conditions, etc. In the United States an important development in the field of metrology is the establishment of the 'Centre for Measurement Science' at the University of Washington D.C. to get the youth of America interested in metrology and provide them with specialised education to pursue it as a career.

STATISTICAL QUALITY CONTROL

Statistical quality control was considered as an integral part of a Quality Control programme in most of the factories. Statistical quality control techniques were utilised for the evaluation, control and improvement of quality in various stages of manufacture. Also in some of the factories Quality Control techniques were applied to non-manufacturing activities, e.g., research and development, design, maintenance, market research, analysis of complaints, clinical applications, sickness, absenteeism and in administration. The most commonly employed techniques were control charts, sampling plans and simple experimental designs. Also techniques like vendor rating, quality index, regression analysis, demerit rating plans were popular. In addition to these, the techniques of evolutionary operations were applied successfully in Japan and USA specially, to chemical processes. Increasing use of non-parametric methods, particularly in connection with sensory inspection, in the industries in Japan were noted. In industries in the United States the evaluation of outgoing product quality by use of the Outgoing Product Quality Rating programme (OPQR), developed by Dodge and Torrey, was in use.

Great importance had been laid on the need for standardisation as an important step to quality control programme. Standardisation at national level in the countries visited was fairly well-advanced and a large number of standards have been published. Apart from the national standards, individual companies evolved their own standards which in many cases were found to be tighter than the national standards so as to ensure that the end product would under no circumstances fall below the specification limits laid down in national standards.

TRAINING

Training in the field of Quality Control had been given a prominent consideration in all the countries and factories visited abroad. Apart from the staff in the quality control department, personnel in various categories—top management, technicians and workers—had been given an understanding of the theory and practice of the Quality Control procedures. The Team noted that in-plant training of personnel at all levels in Quality Control methods was given great importance.

The details of the training programmes organised in Japan (in-plant and outside training) show the extent of training and also by syllabus of training reveal the advanced statistical techniques taught.

In the United States, the Rutgers University (which the Team visited) provides evening courses in Quality Control. The University offers Master's and Ph.D. degrees in Quality Control. Many of the factories around that area have taken advantage of the opportunity provided by the University.

Radio is also used as a medium of Quality Control education in Japan. In USA a course in probability and statistics was presented over the NBC TV network.

PROMOTIONAL ACTIVITIES

Japanese industries which were keenly aware of the need to export uniform quality goods in a competitive market and to reduce their cost

of production were very quick to grasp the utility of quality control techniques. Industrial establishments, research associations, technical societies and the Government of Japan, all collaborated to create a suitable climate for ushering a new era of 'Quality Control' in Japan.

The American Society for Quality Control (ASQC) is the main centre of Quality Control movement in USA. American Society for Quality Control was established in 1946 and now has a membership of 14,000. American Society for Quality Control has 115 sections throughout the USA. The society conducts 850 programmes annually; the programmes include training courses, conferences, seminars, talks, plant workshop seminars, social gatherings, etc.

In the United Kingdom, British Productivity Council has set up a committee for the promotion of Quality Control. The formation of the European Organisation for Quality Control (EOQC) gave a new impetus for the Quality Control movement. In July 1961 the National Council of Quality Control Reliability was formed.

11 : Recommendations

We, the members of the Team on Quality Control in Industry, recommend as follows:

Since the Quality Control programme in any plant will work successfully *only* when the top management takes sincerely the decisive steps to implement, as has been the case in the plants visited abroad, it is recommended that the programme in Quality Control should start developing from the top and spread through the organisation to the operatives level. The concept of total Quality Control is recommended for implementation by managements.

It is recommended that management's thinking and objectives with regard to quality and its control should be clearly expressed and communicated throughout the plant by means of written policy statements and other directives.

Consistent with the evolved policy and directives, an effective organisation structure should be evolved. It is not possible to suggest a single organisation structure to suit all industries. However, the organisation structure (with reference to Quality Control) of Singer Manufacturing Co., Bristol Myers Co., and Eastman Kodak Co., are recommended for consideration by the management.

The constitution of Quality Control committees at various levels on the lines of Japanese industries to guide and implement the programme is also recommended.

It is our opinion that a constant review of schemes for corrective action and evaluation of the Quality Control programme are of utmost importance. For this purpose an effective system of reporting to management periodically is recommended.

In order to develop quality consciousness at all levels in the plant, introduction of suggestion schemes, display of slogans, etc. is recommended.

It is recommended that the aspects of Statistical Quality Control should find a prominent place as they are the only techniques available for quality evaluation, maintenance and guidance for improvement economically. Qualified statisticians trained in industry should be placed in charge of this department.

For the finished products, it is recommended that the industries should invariably adopt the Indian Standards wherever they exist; as they define the quality at the national level, prescribe the means to evaluate it and also lay down sampling procedure for appraising conformance of a lot to the specified quality.

It is recommended that for the intermediate parts and processes, the plants should evolve their own works standards, keeping in view the requirements of the national standards and their own production conditions. The development of company standardisation will also make the introduction of Quality Control easier as was noticed in Japan and USA.

It is recommended that training programmes should be organised at various levels—top management, middle-management, quality control personnel and worker levels. It is also recommended that in-plant training in Quality Control on systematic basis should be given important consideration. It is also the opinion of the team that wherever training programmes, are organised, adequate follow-up procedures should be ensured so that effectiveness of these training programmes is ensured.

It is recommended that a basic course in quality control of advanced nature on the lines of Japanese Union of Scientists and Engineers should be organised periodically for Quality Control professionals.

It is recommended that training programmes and manuals for specific industries be prepared.

The Team members recommend the formation of a National Society for Quality Control as it is of utmost importance at the present juncture for the development of Quality Control movement in India on proper lines. The Team members strongly feel that industrialists, technicians and Quality Control specialists should take lead in the formation of the Society. The work of

the American Society for Quality Control can be taken as a model for this purpose.

The Team members recommend that a periodic publication specially devoted to theory and application in Quality Control should be published as this will stimulate the adoption of Quality Control practices in industry. This publication could be undertaken by the proposed National Society for Quality Control.

The Team strongly recommends the institution of prizes to plants for doing effective Quality Control work and to individuals who make significant contribution in the field of Quality Control. This work also could be undertaken by the proposed National Society.

An annual conference of Quality Control workers and others interested in the Quality Control movement should be organised (in all industrialised centres on a rotation basis). This should be a regular feature under the auspices of National Society.

"QUALITY WEEK"

In order to develop quality consciousness and educate the consumer of the advantages of buying 'quality' products, the Team recommends the observance of a "Quality Week" every year. During the period special meetings, popular talks, conferences and seminars may be organised throughout the country. To propagate the idea of Quality Control, all publicity media like press, radio, etc. should be fully utilised. This work may also be undertaken by the National Society.

The Team recommends that various industrial organisations, technical societies and research institutions may be requested to co-operate in popularising the concept and principles of Quality Control.

It is recommended that the use of certification marks of Indian Standards Institution and of other recognised organisations be encouraged by the companies as they provide a third party guarantee for quality to the consumer.

The Team recommends the early formation of an institution for engineering inspection on the lines of the Institute of Engineering Inspection in UK.

The Team members feel that the Government can play a vital role in the development and implementation of modern Quality Control practices. Government as the largest purchaser can certainly influence the quality standards of the products as was the case in USA during war years. This could be done by the Government and other nationalised industries by adopting scientifically designed sampling procedures for acceptance purposes, which will put indirect pressure on the suppliers to institute Quality Control procedures; Government controlled industries can set up Quality Control departments on the lines indicated in the Report and these may serve as models for others to follow. In addition, Government may undertake independently or through existing organisations, educational programmes in Quality Control for its industries and other officials connected with industry.

It is recommended that the Government should enlarge the scope of activity of the National Physical Laboratory at New Delhi, so that it may function on the same lines as the National Bureau of Standards USA, for the purpose of setting of measurement standards and for calibrations and certification of Master Standards and sub-standards used by the industries.

It is recommended that very close co-ordination should exist between universities and industry as noted abroad. This co-ordination consists in arranging talks and consultation on technical problems.

It is recommended that universities (at least those which are situated in industrial area) should provide comprehensive courses in Quality Control for industrial personnel. The institution of degrees and diplomas in the field will be of great help in the promotion of Quality Control

12 : Appendices

APPENDIX A

Industries and Organizations visited by the Team in India

Names	Products
CALCUTTA	
1. Indian Aluminium Co., Belur.	Aluminium Sheets, Strips, slugs, foil forms.
2. Metal Box Co. Limited.	Metal containers.
3. Jay Engineering Works.	Sewing machines.
4. Imperial Chemical Industries.	Caustic Soda, Pesticides, Paint, Polythene.
5. Bata Shoe Company.	Various types of shoes. Shoes both for home consumption as well as for export.
6. Shalimars Paint and Varnish Co. Ltd.	Varnish and Enamel paints.
7. Guest, Keen and Williams Limited.	Bolts, Nuts, Forgings, Auto-wheels, Railway points and crossings.
8. Indian Statistical Institute (SQC Unit).	Consultants in Statistical Quality Control.
9. Indian Society for Quality Control.	Professional Body.
BOMBAY	
10. Kamani Metals & Alloys Limited.	Non-ferrous rolled sheets, Strips and Foils.
11. Premier Automobiles Limited.	Motor Cars and Trucks.
12. Tata Cloth Mills.	Cloth.
13. Fire-stone Tyre and Rubber Co. Ltd.	Tyres and Tubes.
14. Government Mint.	Coinage.
15. Bombay Textile Research Association.	Textile Research.
MADRAS	
16. Integral Coach Factory.	All metal integral coaches.
17. Addison Paints Co. Limited.	Paints and Lacquers.
18. India Pistons Limited.	Pistons, Piston rings and gudgeon pins.
19. Carborandum Universal Limited.	Bended and Coated abrasives.
20. Western India Match Co., Limited.	Safety Matches and match boxes.
BANGALORE	
21. Bharat Electronics Limited.	Wireless receivers, Transmitters, Trans-Receivers, Valves, Condensers, Crystals, Hearing aids, etc.
22. Kirloskar Electric Co., Limited.	Electric Motors, Transformers and Alternators.
23. Indian Telephone Industries Ltd.	Telephones and P.B.X. Exchanges.
24. Hindustan Aircraft Limited.	Manufacture and overhaul of various types of aircrafts, aero-engines and manufacture of all metal railway coaches.
25. Statistical Quality Control Unit.	Consultants.
26. Quality Control Association.	Professional Body.

APPENDIX B

Industries and Organizations visited by the Team Abroad

Names	Products
JAPAN	
1. Tokyo Shibaura Electric Co., Ltd. (Yanagicho Works).	Transistor Radios, Waithour meters, Household Appliances.
2. Toyo Rayon Co., Ltd. (Shiga Works).	Viscose Rayon, Nylon products, polyster fibre products.
3. Tohoku Works Limited.	Shuttle bodies (part of sewing Machines).
4. Nakayo Communication equipment Manufacturing Co. Ltd., Tokyo.	Telephones, Transmitters, Switchboards, Testing equipment.
5. Tokyo University.	
6. Osaka International Trade Centre.	
7. Japan Productivity Centre. (Discussion meeting with experts in the field of Quality Control was also arranged.)	
USA	
1. Lockheed California Company, Burbauk, California.	Aircraft manufacture and Mo dernisation.
2. Bausch & Lomb, Inc., Rochester, New York.	Opthalmic lenses (single vision and Bifocal), Spectacle Frames, and Scientific Instruments
3. Eastman Kodak Company.	Photographic material, Cameras, projectors, photographic Handware, etc.
4. Bristol-Myers Co., Hillside, New Jersey.	Cosmetics, ethical drugs, and medicinal products.
5. Sonotone Corporation, Elmsford, New York.	Vacuum tubes, ceramic condensers, Nickel cadmium Batteries.
6. Singer Manufacturing Co., Elizabeth, New Jersey.	Sewing Machines, Industrial and domestic.
7. Western Electric Co., Allentown, Pennsylvania.	Solar cells, Alloy transistors, silicon diodes.
8. Radio Corporation of America, Somerville, New Jersey.	Transistors, Ferrites (memory products) for computer and automation.
9. Rutgers University, New Burnswick, New Jersey.	
10. American Society for Quality Control, Chicago, Illinois.	
11. National Bureau of Standards, Washington, D.C.	
12. American Council on Education, Washington, D.C.	
13. US Department of Labour, Washington, D.C.	
14. American Federation of Labour, Congress of Industrial Organisations (A.F.L.-C.I.O.), Washington, D.C.	

Names	Products
UK	
1. Rollys Royce Limited, Derby.	Aero-engines.
2. Dunlop Rubber Company, Birmingham.	Tyres.
3. Joseph Lucas & Co., Birmingham.	Electrical accessories; Voltage controllers, switch gear, magneto, alternators, distributor (ignite).
4. Massey-Ferguson Tractors Limited, Birmingham.	Tractors.
5. N. Corah Limited, Leicester.	Hosiery.
6. Beecham Foods Limited, Middlesex.	Beverages.
7. Hirst Research Centre, General Electric Company, Middlesex.	
8. British Standards Institution, London.	
9. Institute of Production Engineers, London.	
10. Electrical Inspection Directorate, Kent. (Ministry of Aviation).	
11. The British Council, London.	

APPENDIX C

The Challenge of Total Quality Control*

THERE has been an unusual degree of quality control progress throughout the United States in recent years. Through the efforts of many groups and individuals, there has been a very wide growth in understanding about the broad scope, the technical emphasis, the organizational character, and the growth opportunities of the quality control field.

One of the keys to this progress that I see from coast to coast is the degree to which industrial top management has come to take quality control really seriously as an overall management activity. The test that many progressive American company presidents apply to their quality control programme today is not a test of its adequacy as a statistical analysis effort, nor its adequacy as an incoming sampling activity, nor indeed its adequacy as a matter of shop process control effort. The acid and final test that top management uses is a business test—a test of the degree of positive contribution that quality control makes to the effectiveness, service, and profitability of the total enterprise.

This is, of course, because elements of product quality are deeply entwined with the very roots of a company—with its marketing activities, with its inventory control, with its product planning, even with its industrial relations. A mature, genuinely satisfactory modern quality control programme is one which, on an overall, factory-wide basis, regularly comes to grips day by day with all of these product quality elements. The programme may be modestly organized in its early days as a matter of reject analysis alone, incoming sampling alone, process analysis alone. For maximum contribution to business effectiveness, however, its ultimate goal must be overall control of product quality wherever this quality is to be found.

Modern Quality Control Goal

This is a goal under which quality control becomes a genuinely top-level management programme in a company—comparable directly with other top-level management programmes such as Production Management, Budget Control, Materials Management, Personnel Administration. It is, in effect, the goal for building the modern quality control function.

I would like to take the liberty of offering some of my views about what we quality control men must do to achieve this goal toward which there has been so much heartening progress and yet toward which so much progress still remains to be accomplished before quality control can be recognized as a genuinely mature, first team business management function in the United States. I will try to present these opinions frankly. If they occasionally seem blunt, the justification I offer in apology is simply stated. It is my conviction that, after a decade of explosive and successful quality control growth, a broad and searching appraisal of our objectives is in order. We must make sure that our policies and programmes are squared up with the current realities of industry.

I am also convinced that this, our professional journal, is the medium for such an examination. How should we organize? How should we train people? How should we establish plans and programmes? How should we develop equipment fully to achieve our product quality objectives?

Quality as a Business Problem

In coming to grips with questions such as these, perhaps it would be initially worthwhile to look broadly at the quality problem that exists today as a very critical business problem.

To design, build and sell products competitively in the 1957 market-place, American businessmen must take full account of three crucial trends:

1. Customers, both industrial and consumer, have been increasing their quality requirements very sharply in recent years. This tendency is likely to be greatly amplified by the intense quality competition that seems inevitable in the near future.

   For example, the electrical relay that could command the lion's share of the 1952 industrial market is no longer acceptable for 1957 operating needs. Consumers are progressively more minute in their examination of the finish of appliances, or in their judgment of the tone of a ratio or television set. Even for military products on which quality has always been the major consideration—jet engines, airborne electronics, ordnance—specifications are continually being made more rigorous.

2. As a result of this increased customer demand for higher quality products, present in plant quality practices and techniques are now, or soon will be outmoded.

   Thus, the machined part that could once be checked with a pocket scale or a pair of

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* (A. V. Feigenbaum General Electric Company, New York, N.Y., *Industrial Quality Control*, May 1957).

micrometers must now be carefully measured with an air gauge. Material that could once be visually accepted if it were "reddish brown and shiny" must now be carefully analyzed both chemically and physically to assure that it is beryllium copper instead of phospher bronze. At the same time, automation, in which rapid quality evaluation is a pivotal point, has magnified the need for mechanization of inspection and test equipment—much of which is now in the hand-tool stage.

3. Quality costs have become very high. For many companies they may be much too high if these companies are to maintain and improve their competitive position over the long run.

   In fact, quality costs (inspection, testing, laboratory checks, scrap, rework, customer complaints, and similar expenses) have crept up to become a multimillion-dollar item. For many business they are comparable in degree with total direct labour dollars, with distribution dollars, or with purchased material dollars! Evidence points strongly to the fact that many businesses have quality-cost expenditures representing 7, 8, 10 per cent, and even more of their cost of sales!

   Taken together, these trends spell out the twin quality objective of modern American business management: first, considerable improvement in the quality of many products and in many quality practices, and, second, substantial reductions in the overall costs of maintaining quality.

Total Quality Control

In my opinion, the business key to meeting these objectives lies in a kind of activity that we might call "total Quality Control".

The underlying principle of total quality control is that, to provide effectiveness, true quality control management must start with the design of the product and end only when the product has been placed in the hands of a customer who remains satisfied. Furthermore, it must foster the right product quality cost during the entire effort.

The reason for the breadth of this activity is that the quality of any product has been affected not at one but at many stages of the industrial cycle: For example, take the case of an electrical relay:

Marketing evaluates the level of relay quality which customers want and for which they are willing to pay.

Engineering reduces this marketing evaluation to exact specifications.

Purchasing chooses, contracts with, and retains vendors for parts and materials.

Manufacturing engineer selects jigs, tools, and processes for relay production.

Manufacturing supervision and shop operators exert a major quality influence during parts making, sub-assembly, and final assembly.

Mechanical inspection and functional test check conformance to specifications.

Shipping influences the calibre of the packaging and transportation.

In other words, the determination both of quality and of quality cost actually takes place throughout the entire industrial cycle for relay. This is the reason why real quality control cannot be accomplished by concentrating upon inspection alone, or design alone, or reject-trouble-shooting alone, or operator-education alone, or statistical analysis alone—important as each of these individual elements is. The breadth of the job requires instead—to restate the point—a broad-gaged thoroughly competent business management function which has a technical relationship with product quality at all stages of production.

Like traditional inspection, this quality control function is still responsible for assurance of the quality of products shipped, but its broader scope places a major addition upon this responsibility. Quality control becomes responsible for quality assurance at Optimum Quality Costs.

In total quality control, therefore, the typical quality control man is basically a Quality Control Engineer—with an adequate background of the applicable product technology, and with training in statistical methods, in inspection technique, and in other tools useful in the improvement and control of product quality.

Other Quality Control Philosophies

How widely accepted is total quality control? Not yet very widely, if we are to judge by the degree of its use by quality control men in industry.

It may, therefore, serve further to clarify the character of the total quality control management concept if we compare it with other philosophies that are currently very popular. Actually, there have been, and are today, a great many different concepts of the meaning of the term "quality control". The two most widely accepted of these concepts are probably first, what might be called "inspection quality control"; and, second, of course, the concept of "statistical quality control".

Let's turn first to inspection quality control. This activity as practiced today essentially sums down to the traditional inspection function updated and made more efficient by use of certain statistical methods and work-in-process inspection routines. For one example:

Statistically verified sampling plans assure the quality of outgoing lots better and more economically than do the older 100 per cent inspection or the hit-or-miss spot check procedures. For another example:

In-process sampling inspections detect quality errors before too many bad parts have been produced, and are consequently more effective than concentration on final inspection with its risk of producing a large number of bad parts.

The fundamental job, however, is still the historical factory inspection job which is intended to protect the customer by screening bad material from good prior to shipment. The chief inspector is still essentially confined to shop floor controls. The typical quality control man is still basically a well grounded inspection specialist who has had training in useful statistical methods.

True, an impressive weight of dollars-and-cents evidence demonstrates that inspection quality control does indeed represent a great improvement over older inspection practices. And probably most systems called quality control in American business today are examples of the inspection quality control view.

Now for the second most popular concept—statistical quality control.

This approach, as is so well known, reflects the major and increasing contributions that probability methods are making to the improvement of industrial decision making. And the statistical quality control concept predominates, of course, both in the literature of quality control and in professional meetings on the subject. It sees the typical quality control man as a competent industrial statistician, who works on problems ranging from the design of laboratory experiments, through the establishment of control charts for production processes, on to the analysis of manufacturing rejects. It sees him, in other words, as capable of making contributions in fields not directly connected with product quality, such as time study, as safety.

Limitations of the concepts

In my experience, both the inspection Quality Control concept and statistical Quality Control concept have been and are today highly useful in the areas of product quality which they cover. But as compared with total Quality Control, I am forced to suggest categorically that their scope is much too limited; that they are able to provide only a partial grasp of the overall Quality Control problem that faces American businessmen.

This is because the inspection and statistical concepts of Quality Control are simply not adequately geared to the fact that quality considerations are involved in every phase of industrial activity; they are not geared to deal with total costs of quality; their responsibilities and authorities are not geared to effort that is adequate to keep these costs at a minimum; their technical engineering content is too low for the technological complexities of today's product quality.

In my opinion inspection Quality Control and statistical Quality Control—popular as they may be today—will ultimately be recognized, not as ends in themselves, but basically as progress markers on the way toward our real Quality Control management goal of total Quality Control.

I do not minimize at all the fundamental problems that face Quality Control men in converting inspection and statistical programmes to complete Quality Control programmes—problems of organization, of manpower, of salesmanship. But frankly—and this may seem surprising—I believe that total Quality Control represents a concept that is in the long run much more saleable to, understandable by, and acceptable to industrial top management than are the inspection and statistical concepts.

The inspection concept no matter how useful it has been in fact, has in actual practice always been received with substantial reserve by some members of top management. They have—and not without justice—considered the traditional screening inspection process, no matter how much up-graded, as a necessary evil, as a "no value added" activity that is necessary only in the way that policemen are necessary. They have seen inspection budgets as something that must be borne with but which should be trimmed whenever and as soon as possible. They have simply not considered the inspection activity as a member of the management first team, and have not accounted for it in major planning for the business.

And the statistical Quality Control concept, good as it is, has often not been taken by some members of top management even as seriously as they have taken inspection Quality Control. After all, to a businessman whose responsibility is to his company's overall performance, statistical Quality Control is at best an important technique with broad application. Unlike marketing, or industrial relations, or production, however, it is not a fully integrated function to meet basic business objectives.

Reliability Quality Control

While statistical and inspection Quality Control are unquestionably the most popular, there is another current concept that is becoming increasingly recognized. It can be termed as "Reliability Quality Control." Further significant insight may be cast upon the nature of total Quality Control if we briefly relate it to this Reliability Quality Control concept.

Product performance-over-time requirements today are being spelled out in many specifications. These "reliability" requirements are achieved through well understood procedures in long established product lines like locomotives or turbines or generators However, they create major new quality problems in more recent technologies like electronic assemblies which use thousands of components.

To some organizations, solutions of these reliability problems have seemed somewhat unrelated to the application of statistics or of inspection. New, powerful, and useful techniques have, therefore, been developed—techniques, in fields like environmental analysis and non-destructive testing.

Just as was the case in years past with inspection and statistical techniques, these reliability techniques themselves have gradually crystallized into a quality control activity of their own. Quite understandably, some of reliability quality control's practitioners consider their activity at least as technical and specialized as—and, therefore, different from—the statistical and inspection activities.

Nonetheless, and despite its contributions, reliability quality control shares some of the inadequacies of these activities. Like them, its scope is far too limited as compared with the total industrial quality problem.

Product performance-over-time, while very important and currently the object of much attention, still represents only one of the major interdependent elements in the definition of the quality of a product. All such elements are extremely important and all require effort to achieve the overall product quality which will provide satisfactorily reliable customer performance. The achievement of product reliability is operationally interrelated with many other company quality programmes: for instance, with incoming material controls or with in-process control. It cannot really be achieved as an activity separate and distinct from these other programmes, no matter how powerful the individual techniques it employs.

Because it has come to prominence later than the statistical or inspection concepts, reliability quality control has generated some additional, negative management reactions. These have to do with the possibility of costly pyramiding of the various Quality Control activities. There is concern about overlaps between reliability Quality Control and the other specialized Quality Control concepts that may be operating in the plant; concern about its possible competition rather than integration with these other concepts; concern, in certain cases, about the extent to which the reliability approach differs from these concepts more in the fresh emphasis of its language than it really does in strong new tools that it brings to the plant.

Management men have questioned the rather forced attempts to reconcile reliability Quality Control with the other concepts through such rationalizations as the following: that "quality" work is basically in-plant and this is the job of statistical or inspection Quality Control; that, on the other hand, "reliability" work has to do with achieving consistent field performance. Some management people do not consider this a genuinely workable distinction.

For similar reasons, they question equally sharply the opposite rationalization that is occasionally offered; that if consistent field performance is emphasized, then reliability Quality Control can largely replace the in-plant work of inspection or statistical Quality Control.

Certainly, the business quality problem is made no easier when top management is faced periodically with reconciling the various special-purpose Quality Control concepts. Management may feel a deep and continued doubt concerning what "quality control" is really all about. It wonders when the now-new reliability Quality Control concept will itself come into conflict with a still never special-purpose concept of Quality Control. It wonders why Quality Control people can't adopt a common language and why they can't deal with quality problems as management sees them.

Total Quality Control Most Acceptable

To sum up that part of my message, therefore, I propose that total Quality Control not only is the function which can do the broad Quality Control job needed by American business today, but—as an inevitable corollary—it is also the Quality Control concept that is most acceptable to American business: because it is an integrated whole; because it operates at lower cost; and because it comes to grips with the complete range of product quality and quality cost problems as top management sees these problems. As a result, total Quality Control is an activity that can begin to give truly technical and professional status to Quality Control men. But more about this in a moment.

Now let's turn directly to management of the Quality Control function on this broad basis:

The work of the function may be classified into four broad jobs.

1. *New Design control*, or the planning of controls for new or modified products prior to the start of production.

2. *Incoming material control*, or the control of incoming purchased parts and materials.

3. *Product control*, or the shop floor control of materials, parts, and batches from machines, processes, and assembly lines.

4. *Special process studies*, or the conducting of special analysis of factory and processing problems.

In these four jobs, the modern Quality Control function has, it may be worth re-emphasizing, two basic responsibilities:

First: To provide QUALITY ASSURANCE for the business products: that is, simply, to be sure that the products shipped are right.

Second : To assist in assuring OPTIMUM QUALITY COSTS for those products.

The Quality Control function fulfils these responsibilities through its three sub-functions: which are Quality Control Engineering; Inspection; and Test. They in turn operate three activities, which form a continuous feedback cycle:

(1) Quality Planning is done by Quality Control engineering; this establishes the basic framework of the quality control system for the business' products.

(2) Quality Measuring is performed by inspection and test; this determines, in accordance with the quality plan, the conformance and performance of parts and products with engineering specifications.

(3) There is rapid feedback to Quality Control Engineering for Quality Analysis, which results in new planning, thus completing the cycle. This analysis also fosters corrective action for product quality deviations.

Quality Control Engineering Work

The true nerve centre of the modern Quality Control function is this engineering component. Its feedback cycle activities deserve examination in some detail as they fit into the four Quality Control jobs:

First : New Design Control.

In this area, Quality Control engineering provides three main activities:

1. Preproduction service to design engineering and manufacturing engineering in analyzing the quality-ability of new products and production processes, and in de-bugging quality problems. This assures a product which will be as defect-free as possible prior to the start of production. Among the new technical tools which the Quality Control engineer brings to this effort are process quality capability studies, tolerance analysis technique, pilot run practice, reliability analysis, and wide variety of statistical methods.

2. The planning of inspections and tests to be carried on when production is under way on the new product. This is to establish continuous control of in-process quality. It involves determining the :

Dimensions and characteristics of the parts to be checked.

Degree to which they are to be checked.

In-process and final production points at which checks are required.

Methods and procedures to be used—including statistical sampling plans, control charts, etc.

Personnel who will make checks; that is, which shall be done by production operators, and which by the inspection and test subfunctions.

3. Design of modern inspection and testing equipment. This is genuine quality control equipment rather than merely mechanized sorting. It is physically integrated to the fullest possible extent with manufacturing equipment to permit the machine to check its own work. The aim of this design activity is economical investment expenditures, maximum equipment utilization, and fullest practical mechanization and automation both of operations and of quality control paperwork.

Second : Incoming Material Control.

In this area, quality control engineering must assist in the establishment of good quality relationships with suppliers. It contributes to this objective in the following ways:

By planning the periodic rating of the quality performance of present suppliers, it provides facts which assist the purchasing function in quickly bringing satisfactory or unsatisfactory quality performance to the attention of venders.

By evaluating the quality capability of potential suppliers, it provides facts which assist purchasing to select good quality vendors.

By working with the vendors, it assists them in understanding the quality control requirements of the purchase contracts they have won.

By establishing quality certification programmes, it places the burden of quality proof on the vendor rather than on an extensive, expensive in-plant incoming inspection effort.

Third: Product Control.

In this area, quality control engineering carries on the cost measurement and quality cost reduction project activity required for over-all quality cost control and reductions; and it works closely with the inspection and test sub-functions which perform the actual measurement work. It also performs process quality capability studies to determine the quality limits within which a machine or process may be expected to operate. The aim is to make sure that parts will be routed to equip-

ment which is capable of economically maintaining engineering specifications.

Fourth : Special Process Studies.

In this area, the job of quality control engineering is to analyze complex, in-process quality problems which have been fed back to it by inspection and test. These studies are directed both to the elimination of defects and to the development of possible improvements in present quality levels.

The Professional Quality Control Engineer

Certain elements of this quality control engineering work have been previously performed on a sporadic basis. But the quality control engineer himself is something new under the sun. Quality control engineering is not merely a new label for the inspection planning package, nor a fresh designation for the test equipment engineer; nor yet a technologically flavoured title for the industrial statistician. It is, instead a specialized technical activity with a character all its own, calling for a unique combination of skills in appropriate phases of product and process technology, as well as in the quality control technique itself.

Quality control engineering work is the product of cross-fertilization of several modern developments—in statistical methodology, in fast-response, high-precision inspection and testing equipment, in management engineering progress in development the control function in modern business.

In experience, education, aptitude, and attitude, the man we see entering quality control engineering work today is, in fact, not very different from the man entering other longer-established maior technical fields, for example, product engineering or manufacturing engineering. He must possess, or have the capacity to acquire, the necessary product and process background. He must have the personal characteristics to work effectively in a dynamic atmosphere with people of diverse interests. He must possess the technical background which will enable him to acquire, if he does not already have it, the growing body of quality control engineering knowledge. Finally, he needs the analytical ability to use this knowledge in solving new and different quality problems. In this broad type of quality control engineering I think we are beginning to see the emergence of a truly new professional activity in the engineering sector of the American economy.

Quality Control Inspection and Test

It is worth noting that the planning and analysis work of the quality control engineer, in turn, makes possible the employment of a new, more positive type of inspector and tester. Instead of Policing the manufacturing process, the modern inspector and tester becomes a direct part of that process team by assisting in the production of good quality products.

This positive type of quality control inspection requires only a very minimum of routine, hand-sorting inspection and test as we have known it in the past. Instead, the inspector and the tester do genuine quality assurance work. They provide genuine assistance in the production of the right quality by :

first—becoming auditors of the good quality practices that have been established by quality control engineering;

second—by providing to foremen and operators as much as possible on-the-spot shop-floor analysis of defects;

third—by feeding back when necessary facts about these defects for corrective analysis and action elsewhere.

Such work of course means the up-grading of traditional inspection and tests as we used to know it. As compared with this older activity, Quality Control Inspection and Test requires may fewer but much more highly qualified and more specialized people—those who have genuine ability to be helpful in making the right quality. An instance in point is the arc-welding inspector, who not only knows whether or not weld penetration on a part is satisfactory; but also, in the case of defective welds, may be able to counsel the shop on why the penetration has been unsatisfactory.

Two Organization Principles

Perhaps it would be appropriate to pause for a few moments to turn to the important question of just how this total quality control activity can be organized for a company. Experience shows that two organizational principles are basic to guide us here.

Principle number one is that Quality is Everybody's Job in a business.

In defiance of this principle, there have been many company experiments over the years which have attempted to make the quality activity cycle less of a decentralized, Tinkers-to-Evers-to-Chance sequence. Often these attempts have taken the form of centralizing all quality responsibility by organizing a component whose job was handsomely described as "responsibility for all factors affecting product quality".

These experiments have had a life span of as long as six months—when the job incumbent had the advantage of a strong stomach, a rhinoceros hide, and a well-spent and sober boyhood. Others not similarly endowed did not last six months. For the simple fact of the matter is that the marketing

man is in the best position to evaluate adequately customers's quality preference; the design engineer is the only man who can effectively establish specification quality levels; the shop supervisor is the individual who can best concentrate on the building of quality.

Total quality control programmes therefore require, as a first step, top management's re-emphasis on the responsibility and accountability of all company employees in new design control, incoming material control, product control, and special process studies.

The second principle of total quality control organization is a corollary to the first one. It is that Because Quality is everybody's Job in a Business, It may Become Nobody's Job. Thus the second major step required in total quality programmes becomes clear. Top management must recognize that the many individual responsibilities for quality will be exercised most effectively when they are buttressed and serviced by a well-organized, genuinely modern management function whose only area of specialization is product quality, and whose only area of operation is in the quality control jobs.

Some Results

Experience in an increasing number of companies shows that operation of the total-quality-control programme has paid off handsomely. For one example, a midwestern company manufacturing motors installed a total-quality-control activity, which in 12 months (1) improved product quality substantially, (2) reduced field complaints several fold, and (3) reduced the going level of quality costs from an annual rate of about a million dollars a year to a new annual rate of something over $600,000—a total savings of almost $400,000. And during this period, output increased about 10 per cent.

More broadly, total quality control in the United States has resulted in six important improvements.

Better product quality.

Reduced scrap, complaint, inspection, and other quality costs (Improvements of one third or more in over-all quality costs are not unusual).

Better product design.

Elimination of many production bottlenecks.

Improved processing methods.

Development of a better spirit of quality-mindedness on the production shop-floor.

Certainly our experience with this programme has been highly satisfactory in the General Electric Company, where we have been developing this concept and procedure for some years.

Quality Costs

Thus in its actual practical total quality control successfully meets business' twin-sided quality problem of better quality at lower quality costs. The reason for the satisfactory better quality can be clearly understood from the very nature of the prevention-centered step-by-step technically thorough programme. But the explanation for the accompanying by-product of lower over-all quality cost may not be nearly so obvious.

The reason for the favourable cost result of total quality control is that it cuts the two major cost segments of quality (which might be called failure and appraisal costs) by means of much smaller increases in the third and smallest segment (prevention costs). Why this is possible can be seen as soon as the character of these three categories is considered:

(1) Failure Costs are caused by defective materials and products that do not meet company quality specifications. They include such loss elements as scrap, spoilage, rework, field complaints, and so on.

(2) Appraisal Costs include the expenses for maintaining company quality levels by means of formal evaluations of product quality. This involves such cost elements as inspection, test, quality audits, laboratory acceptance examinations, outside endorsements.

(3) Prevention Costs are for the purpose of keeping defects from occurring in the first place. Included here are such costs as quality control engineering, employee quality training, and the quality maintenance of patterns and tools.

In absence of formal nationwide studies of quality costs in various business, it is impossible to generalize with any authority about the relative magnitude of these three elements of quality cost. However, it would probably not be far wrong to assert that failure costs may represent from one-half to three-quarters of total quality costs, while appraisal costs probably range in the neighbourhood of one-quarter of this total. In many businesses, however, prevention costs probably do not exceed one-tenth of the quality cost total. Out of this 10 per cent, usually 8 to 9 per cent are directed into such traditional channels as pattern and tool maintenance and the specification-changing or interpreting work of product engineering. This leaves only 1 or 2 per cent for elements of quality control engineering work.

It is a significant fact that, historically, under the traditional inspection function, failure and appraisal costs have tended to move upward together, and it has been difficult to pull them down once

they have started to rise. The reason for this relationship is that:

As defects increase—thus pushing up failure costs—the number of inspectors has been increased to maintain the "they shall not pass" screen to protect the customer. This has pushed up appraisal costs.

For the reasons mentioned earlier in this article, screening inspection does not have much effect in eliminating the defects, not can it completely prevent some of the defective products from leaving the plant and going into the hands of complaining customers. Appraisal costs thus stay up as long as failure costs remain high. The higher these failure and appraisal costs go, the higher they are likely to go without successful preventive activity.

Why Quality Costs Drop

Once these two main elements of quality cost have started to rise—as they seem to have throughout industry generally today—the one best hope for pulling them to earth again seems to be spending more on the third and smallest element, namely, prevention cost. The 10 per cent now spent may well need to be doubled, much of the increase going for quality control engineering as well as for improved methods of inspection and test equipment automation.

At first glance such increases in prevention costs may not seem to be in the interest of quality cost improvement, but this objection is rapidly dispelled as soon as results are considered. Translated into quality cost terms, the operation of total quality control has the following sequence of results:

(1) A substantial cut in failure costs—which has the highest cost reduction potential of all quality cost elements—occurs because of the reduced number of defects and the improvements in product quality brought about by modern quality control practice.

(2) Fewer defects mean somewhat less need for routine inspection and test, causing a reduction in appraisal costs.

(3) Better inspection and test equipment and practices, and the replacement of many routine inspectors by less numerous but more effective quality control inspectors and testers, bring about additional reduction in appraisal costs.

(4) Because the new quality control inspection and test is effective in preventing defects, appraisal dollars for the first time begin to exercise a positive downward pull on failure costs.

Quality Dollar Budgeting

It is worth noting that this identification and analysis of quality costs permits a major forward step in the business budgeting process. It makes feasible establishing the dollars needed for quality control, not on the basis of historical inspection cost experience, but on the basis of current company objectives in product quality and quality costs.

Quality needs and problems differ so much from company to company that it is not realistic to generalize about the specific mix of quality costs that should be budgeted under total quality control. But the direction of budgetary trends may be suggested by an example, which embodies current industrial experience in this area.

Table I (next page) shows how one company expects to cut its quality costs by a total quality control programme. The company anticipates that total quality expenses will drop from the current high of 7 per cent of sales to 5 per cent, with declines achieved both in failure and appraisal costs while prevention costs increase from 0.70 per cent of sales to a still modest 1.25 per cent. In this example, the cost savings budgeted are rather moderate, owing to the presence of complicating factors such as the following:

An anticipated 50 per cent increase in sales over the next five years—from $50 million to $75 million.

Planned additions to a product line that is already highly technical and diversified, hence accompanied by major quality problems.

Such a planned 30 per cent improvement in quality cost ratios is feasible, indeed conservative, with a successful total quality control programme—even with a 50 per cent business expansion and even with counterbalancing quality cost increases brought about by the introduction of new products. While the company in the example may not be typical (probably there is no such thing as a typical business enterprise), it is at least illustrative of the good results that can be achieved even when circumstances pose unusual difficulties.

The ultimate end result of total quality control, therefore, is that its programme to improve product quality also brings about both a sizable reduction in total quality costs, and a major alteration in the proportions of the three quality costs segments. No large, long-term personnel increase in the overall quality control function is required as a necessary condition for this quality cost improvement. Instead, the amount of quality control expense, as a proportion of total company expense, will be down in the long run. The personnel mix of the quality control function will, however, change to include a very much higher proportion of professional and specialist-type people.

TABLE—1

Budgeted Quality Costs and Savings Under Total Quality Control
(Assuming sales increase from $50 million to $75 million)

Quality cost element	Total Dollars		Percent of Sales		Percent of total quality cost	
	Present	5-year goal	Present	5-year goal	Present	5-year goal
Failure	$2,275,000	$2,062,500	4.55%	2.75%	65%	55%
Appraisal	875,000	750,000	1.75	1.00	25	20
Prevention	350,000	937,500	0.70	1.25	10	25
Total	**$3,500,000**	**$3,750,000**	**7.00%**	**5.00%**	100%	100%

Summary & Conclusion

In summary, therefore, total quality control represents a major forward step in management science: Its integration of design-through-shipment control of the many elements in the quality picture makes it much more effective than the unlinked fragmentary inspection or statistical controls of the past. Its quality control function, a major new business management activity, provides professional effort in meeting the objective of assured product quality at minimum quality cost.

In this modern quality control function, inspection and test have a chance to develop in the direction that conscientious inspectors and testers have always sought: that is, into an activity with a positive role in assisting other members of the manufacturing, engineering, and marketing team toward quality improvement and quality cost control. No longer are inspection and test confined to essentially a negative, fist-shaking role in sorting bad parts from good, a role placing them continually on the defensive and evoking the hostility of other managers.

In the integrated quality control function, the many tools of statistical methodology that have proved practical and useful can be brought to their fullest effectiveness. With the quality control engineers as tool builders, and the quality control inspectors and testers as tool users, statistical techniques can be put to work in a down-to-earth fashion that welds them into regular day-by-day controls. No longer will these be treated—as too often in the past—merely as curiosities, to be employed in special situations on a pinch-hitting basis.

With product reliability recognized as a major objective, appropriate elements of its tools and practices can be made an integral part of the work of the quality control engineers and of quality control inspectors and testers.

With equipment for inspection and test a direct and major responsibility of the quality control function, more use can be made of equipment specialists who wish to concentrate their skills on the great needs, opportunities, and unique complexities of today's quality control equipment field.

Total quality control thus welds all of this new technology into a strong yet flexible weapon, capable of successfully coming to grips with the three major quality problems that modern business must face and solve: the upward customer pressure on quality levels; the resulting rapid obsolescence of quality practices; the very high level of quality costs.

Although delivery and other factors may sell a product the first time, it is usually quality that keeps the product sold and which keeps the customer coming back a second and a third time. Quality cost —perhaps 8 per cent or more to cost of sales—is one of the major elements of product cost that must be made right to permit the setting of the right price to the customer. Helping to assure this right quality cost is the way The New Total Quality Control can serve its company in the years ahead—in which product quality, and modern quality control operated as a management function, will be among major factors in the company's survival, health, and progress.

I respectfully submit for consideration this conclusion: that learning to build and use these broad, total quality control programmes must—fully as much as statistical and inspection specialization—become a major basis for professional skill in the qualifications of we quality control men.

APPENDIX D

The Basic Work Elements of Quality Control Engineering*

THIS article represents an effort to provide a statement covering the Basic Work Elements of Quality Control Engineering. It was prepared by the Committee for Development of Basic Work Elements under the direction of the General Professional Council of the American Society for Quality Control.

An effort has been made to be very general in order that the document would be directly applicable to a broad variety of industrial and governmental situation. Material which would have been of value in describing work elements in some areas has been omitted if it detracted from the general validity of the document.

It is emphasized that this document is restricted to the engineering aspects of control of quality. Other occupational areas in the Quality Control field are not covered, although they may include some of the elements appearing in this document.

The Basic Work Elements are designed to serve as the foundation for building the professional stature of our society. It provides a much needed guide for Quality Control Engineers and Industrial Managements in establishing and guiding their Quality Control programmes. Colleges and Universities will, no doubt, utilize this information in the development of future curricula.

A Broad Definition

The ultimate objective of all Quality Control endeavor is to provide quality assurance for the finished product and to assure optimum quality costs for that product. To accomplish this objective, every producer needs an integrated programme for the control of product quality including its reliability elements comprising the basic work elements described herein. The totality of the work elements is not, of course, intended to describe the work of any single Quality Control Engineer, nor the work of any particular Quality Control Organization. A Quality Control Engineer may specialize in only one or a few of these elements and still be performing legitimately professional work. Quality Control Engineering encompasses the planning, the control, the evaluation, and the reporting of all quality aspects of the product from its conception through manufacture, processing, storage, delivery, installation, maintenance, and repair to the end of its service life.

All the functions of an organization have specific responsibilities for product quality. Quality Control Engineering does not seek to usurp any of these functions. However, it does afford an effective means of providing each supervisor and engineer with specific and overall quality and cost views to enable him to make decisions leading to optimum product cost and quality.

In like manner, of course, all functions of an organization contribute to the reliability elements of product quality. Ultimate reliability cannot exceed that which is designed into the product. Continued achievement of the design reliability is dependent upon strict control of all material and process characteristics which maintain the integrity of the design. Logically, therefore, those activities related to product reliability are appropriately reflected in all the principle work areas of the Basic Work Elements.

In the new design area, Quality Control Engineering aids in the development and analysis of new products and processes, and works to eliminate future quality problems. Economical incoming material control procedures, which include supplier process controls, are the responsibility of Quality Control Engineering. In-plant process and product control and evaluation and assurance of the quality and reliability of finished goods are also prime Quality Control Engineering responsibilities. Finally, Quality Control Engineering includes evaluation of in-process, finished, and field inventories. All of these elements make up the hard core of Quality Control Engineering.

The activity which ties together and directs the planning, control, evaluation, and reporting of all the quality aspects of the production task is truly engineering. It is characterized by creative work. Statistics, technical process and product knowledge, and practical shop experience are combined in attaining the goal of optimum quality product at lowest possible cost.

Certain work elements of Quality Control Engineering are general in nature and have application in all phases of the Quality Control job. Regardless of the area of his specialization, several or all of the following elements comprise an important part of the Quality Control Engineer's job.

TRAINING: Prepare current educational material for conducting training programmes in 11 aspects of Quality Control including Statistical Control Train at all levels of the organization. Keep abreast of new developments in

*General Professional Council, American Society for Quality Control.

the field for purposes of training and application.

QUALITY STANDARDS: Develop and implement quality standards where needed in the organization. Train members of the organization in their use.

MEASUREMENT AND ANALYTICAL FACILITIES: Determine, recommend, and/or design measurement and analytical facilities required to make evaluations of product quality and reliability. Develop and maintain an economic programme for periodic precision and accuracy checks, for calibration and for maintenance of all jigs, fixtures, physical testing, measurement, and analytical facilities.

METHODS AND PROCEDURES: Develop forms and instructions to be used for collecting, analyzing and reporting quality and reliability data. Institute procedures for identifying responsibility and for implementing corrective action.

DISCREPANT MATERIAL: Establish and implement clear concise procedures for the disposition of discrepant material. Determine responsibility and the proper allocation of extra costs involved.

AUDIT OF THE QC PROGRAMME: Provide methods and arrange for auditing and reporting the implementation, effectiveness, cost, and savings of the QC Programme.

New Design

Quality Control Engineering activities in the new design field threat through all the preproduction activities from conception of the product to trial runs. Application of QC Engineering effort in this phase of the job means improved, less costly product incorporating all the knowledge obtained from previous designs or research. Quality Control Engineering will minimize process control problems from the day production begins. Several or all of the following specific activities are involved in this area.

PRODUCT AND PROCESS RESEARCH: Conceive and analyze designed experiments and tests to gain further knowledge of the variables affecting component, product, and process quality and reliability. Devise means of evaluating other manufacturer's designs. Analyze and report results.

SPECIFICATIONS: Prepare and present data summarizing field, manufacturing and vendor complaints on previous designs. Recommend to design engineering specifications which will eliminate these problems from the new design.

TOLERANCES: Use statistical methods to predict overall tolerances of proposed designs based on previous process capability studies. Submit to design engineering tolerance recommendations which enable desired overall tolerance to be met and at the same time allow individual dimension tolerances to be within process capabilities.

INITIAL SAMPLES: Plan tests, inspections, and statistical studies on initial product samples. Analyze results to verify realization of design quality and reliability objectives.

METHODS OF ACHIEVING QUALITY PRODUCTION: Recommended to production engineering process improvements including fixtures, tools, jigs, inspection, and testing devices required to achieve process control and maintain desired quality and reliability.

FINAL DESIGN ANALYSIS: Analyze tolerances, specifications, and dimensions of final design to assure that the product can be manufactured as planned. Make recommendations to design engineering on tolerance problems for possible modification.

TRIAL RUNS: Determine parameters of trial lots to be measured and controlled. Analyze results. Predict the performance of future production lots. Prepare a report of trial data for design engineering and for a permanent record.

CONTROL OF PRODUCTION LOTS: Summarize all the information learned in Steps 1 to 7 and make recommendations for use in establishing economical methods of measuring and controlling production.

Incoming Material

The control of overall product quality is inseparably linked with the quality of purchased material. Quality Control Engineering, therefore, has a contributing responsibility in the selection of suppliers and a direct responsibility for economic control of the quality of incoming materials and for providing evaluation and feedback to other functions to assure the procurement of quality materials at the most favourable cost. The following Quality Control Engineering functions provide for the accomplishment of this objective.

SUPPLIER CAPABILITY: Evaluate supplier quality performance capability and develop quality performance ratings for use by Purchasing in their selection and development of material suppliers.

QUALITY REQUIREMENTS: Provide suppliers, through purchasing, with clear, concise

quality and reliability requirements. Follow up to assure adequate understanding and suppliers action to meet these requirements.

CERTIFICATION: Work with suppliers to establish quality certification plans based on adequate procedures and controls at suppliers' plants to minimize the cost of assuring the quality of incoming materials.

INSPECTION METHODS: Develop, instal, and maintain inspection and analytical procedures including economical sampling plans to determine the quality level of incoming material. Insure compatibility of these procedures between supplier and incoming inspection.

DOCUMENTATION AND FEEDBACK: Establish and monitor systems for recording and reporting supplier conference to quality and reliability requirements.

Process

Utilizing statistical, engineering, and administrative Quality Control methods, develop, instal and maintain economic process controls to achieve and retain process capabilities. The objective of these controls is to maintain operating costs while product quality is retained or improved to acceptable standards. The following are several specific techniques Quality Control Engineers may use to accomplish process control.

CAPABILITY STUDIES: Make capability studies of production equipment and processes. Determine the measurements to be taken, the analysis of data, and the action to correct undesirable conditions.

PROCESS CONTROLS: Establish measurements and process controls to maintain economic control, and to detect entry of any factors that might adversely affect product quality or reliability. Provide adequate written and verbal instructions to personnel performing process control activities.

PERIODIC REVIEW: Review process controls periodically to adjust for changing conditions and to minimize process control costs.

TROUBLE SHOOTING: When out-of-control conditions develop, assist operating and engineering personnel to identify and eliminate causes, using statistical techniques, where applicable.

DESIGNED EXPERIMENTS: When either quality or cost of a controlled process is unsatisfactory, design and conduct experiments to point out process improvements and desirable changes of product specifications. Recommend or authorize changes necessary to effect improvement.

Product Evaluation

Develop, instal, and maintain inspection practices and product evaluation procedures to insure that only acceptable quality product is shipped. To accomplish this objective, Quality Control Engineering activity should encompass the following functions.

INSPECTION METHODS: Develop, instal, and maintain inspection and analytical procedures to determine the quality level and permit the acceptance of satisfactory product. Insure compatability of these procedures between process and product acceptance.

SAMPLING PLANS: Develop and implement economic sampling plans and procedures.

FEEDBACK: Provide for both routine and special feedback and analysis of inspection results so that corrective action can be taken when necessary.

QUALITY LEVELS AND DEFECT CLASSIFICATIONS: Development and implement quality levels and appropriate defect classifications for quality rating of completed product and associated packaging compatible with consumer requirements and capabilities of the production processes.

AUDITING: Develop and instal methods and procedures for auditing, evaluating, certifying and reporting the quality and reliability of product shipped.

COMPLAINTS: Analyse customer complaints and field reports. Identify causes and responsibility and initiate corrective action.

Inventory Evaluation

The deterioration of materials and finished products in use of in storage is an important problem to both producers and users. Economical, reliable evaluation, factual analysis, and engineering judgement applied to inventory quality problems provide management with deterioration curves, maintenance requirements, and feedback information to maximize life. These functions of Quality Control Engineering minimize costs and maximize life. These functions of Quality Control Engineering minimize costs and maximize product serviceability.

SAMPLING: Apply economical statistical sampling procedures to appraise inventory quality.

QUALITY PROJECTION: Using the results of periodic samples, establish and interpret deterioration curves to enable management to maintain desired levels of acceptable quality stocks.

FEEDBACK: Based on sampling results, provide feedback to design, purchasing, and production which will aid in maximizing inventory serviceable life.

PROCESS CONTROLS: Provide and implement process controls for repair, maintenance, reprocessing, and disposition of materials and products in inventory or service.

MANAGEMENT INVENTORY POLICIES: Recommend on the basis of inventory quality and reliability history, those inventory policies which will result in optimum quality and cost of maintaining serviceable materials or products.

Special Studies & Activities

Under this heading fall those work elements which will result in wider and more complete use of SQC techniques. General in nature and not directly connected with day-to-day quality problems, they should nevertheless, be part of every QC Engineer's responsibilities.

NEW TECHNIQUES: Develop new techniques and approaches for the analysis of quality problems.

SPECIAL STUDIES: Assist in applying SQC methods and principles to other managements functions such as Operations Research, Safety, Finance, and other administrative applications.

ADVANCEMENT OF QC ENGINEERING: Promote the objectives and applications of SQC through activity in professional organizations. Contribute to the advancement of QC Engineering through the preparation of technical papers for presentation at meetings, seminars, and conventions, and for publication in company and national magazines and books.

Basic Work Elements Committee Members

Chairman—G. A. Endrich, Heavy Military Electronics Department, General Electric Co., Syracuse, N.Y.

R. Schin, Western Electric Co., Grandview, Mo. Mr. Schin was chairman of the committee from its inception in October, 1958, to September, 1960.

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The committee reported to Dr. A. V. Feigenbaum, Vice-President for professional development, American Society for Quality Control.

APPENDIX E

Responsibilities of Quality Control Organization

(Radio Corporation of America, USA)

DETERMINE whether product which fails to conform to engineering requirements, specifications, standards, or recognized standards of good workmanship shall be held or released for shipment.

Issue reports showing quality levels and trends.

Make recommendations for the correction of any subnormal quality conditions or trends observed and/or the correction of any conditions not conducive to the manufacture of product of satisfactory quality.

Make engineering appraisals of the quality of output of products, based on analyses of the results of statistical sampling inspections, quality surveys, special investigations and complaint history. These appraisals involve a determination of the degree of conformance to design intent as expressed in the specifications or standards.

Assess defect seriousness with regard to the effect of the defect on usefulness of product and develop adequate process controls for prevention of defects.

Evaluate product quality as well as determine optimum quality levels capable by the process based on an economic balance between the needs of the customer (or the department to which a product component is being sold) and the costs of manufacture.

Develop methods for improving the accuracy of the quality appraisals and the presentation of data.

Serve as a point of contact with the customer, including liaison with resident government inspectors and other customer representatives, on matters pertaining to quality of products supplied to them by the manufacturer.

Conduct sampling inspections of completed products, sub-assemblies, piece parts and materials to standards or specifications. This entails sampling inspection for control of process quality as well as protection of lot quality.

Conduct special investigations, tests, and inspections to determine product conformance to engineering assembly or other requirements where such requirements cannot be adequately checked in other regular inspections.

Investigate Warehouse, Stockroom, and product storage areas with respect to unsatisfactory quality conditions observed or reported, in current product and make recommendations for disposition of any effected stocks.

Investigate all complaints and adverse reports on the quality of products for which the Company is responsible and make recommendations to prevent recurrence of the unsatisfactory conditions.

Withhold from delivery any product which is not considered satisfactory for customer's use.

Consult with Engineering (Production, Process or Design) when unsatisfactory conditions exist or may likely occur which is considered likely to adversely affect product quality.

Render final approval for the use of non-standard quality parts, materials or product when emergencies require and its use is not detrimental to the manufactured product. An NSQ is to be signed by Manufacturing, Production Engineering, and Process Control authorizing this use of non-standard material.

Control issuance, approval, and records of PRC's covering waivers of shipment of finished product not meeting specifications but required for shipment by the customer. Approvals for PRC's, in addition to Quality Control, include Engineering, Marketing, Sales, Manufacturing, Production Engineering and Production Control.

Approve Engineering, Manufacturing, Design, or Process changes (Standardizing Notices) which have a direct effect on product quality and/or affect process inspections or incoming inspection.

Issue product, deviation codes as required to identify production and engineering changes, maintain records and control of such codes.

Collaborate with Engineering in setting up specifications and inspections for new parts, components or processes. Aid in determining completeness, adequacy, and accuracy of specifications required in product manufacture.

Determine inspection points and inspection plans and procedures.

Specify testing and gauging equipment to be used for Quality inspections. Teach use of testing equipment and instruct testers in the test procedures and understanding the results obtained.

Prepare adequate instructional information to train new Quality Control personnel and maintain uniformity of Quality Control practices. Assist in training. Engineers, Foremen, Supervisors, and all

personnel in applications of Quality Control practices.

Make statistical analysis of product quality and report all subnormal quality conditions to interested manufacturing organizations as soon as observed. Prepare detailed reports of quality trends and quality items of major interest for management.

Provide Quality assurance that products shipped are satisfactory.

Obtain adequate test and inspection equipment to perform the duties outlined herein. Also arrange for the maintenance of such equipment on a scheduled basis to insure its designed accuracy at all times.

Duties & Responsibilities of Quality Control and Reliability Engineering Department (Western Electric Co., Allentown Works, USA).

General

Stimulate and promote enthusiasm for and understanding of quality control and statistical principles and techniques throughout the Works' organizations including Operating, Engineering, Inspection, Purchasing, etc.

Develop and issue or cause to be issue, appropriate management reports to periodically show progress and results of product quality, cost, etc.

Coordinate the resolution of problems arising in connection with the application of Quality Control techniques.

Keep up-to-date on developments in Quality Control and statistical methods. Maintain contact with other locations to permit a free interchange of information and progress.

Collaborate with Data Processing for devising sure and faster methods of analyzing data from Engineering, shop and inspection studies and experiments. Publicize these methods and coordinate use.

Provide statistical clerical services to Q.C. Engineers and Technical Assistants assigned to Product Engineering Departments. Maintain and periodically issue active lists of control chart in file. Provide copies of charts for process checkers. Locate and call to the engineer's attention, charts not being used by the shop.

Recruit and train engineers in statistical concepts particularly associated with collecting, analysing and interpreting data from engineering studies and designed experiments for eventual transfer to Product Engineering Departments.

Training

Prepare training material, including manuals, visual aids and handouts.

Schedule and conduct:

(a) Basic (6 hr.) course for process checkers, layout operatrs, machine setters, etc.

(b) Basic (12 hr.) course for engineers and supervisors.

(c) Designed Experiment (20 hr.) course for engineers and supervisors.

(d) Sampling (10 hr.) course for inspection, supervisors, engineers and inspectors.

(e) Refresher (3 hr.) course for engineers and supervisors.

Special Studies & Experiments

Undertake the advancement of engineering and shop personnel's knowledge of experimental methods analysis and interpretations by means of lectures, training courses, **conducting** experiments and circulating write-ups, periodic memos on experimental procedures and experiments from outside sources, etc.

Conduct special studies employing experimental procedures with emphasis on process and product improvement and cost reduction. Studies to include compatibility of field requirements and reliability with shop performance.

Reliability

Study the impact of reliability considerations in other companies and plan and coordinate the introduction of these concepts on our products.

Obtain a working knowledge of reliability concepts, principles and techniques.

Assume responsibility for specifying and/or approving procedures and methods of determining reliability of product. Review present life-test procedures and specifications for improvement and standardization.

Conduct special studies such as stressing for the purpose of determining reliability requirements and procedures.

Prepare and present material for training engineers in reliability concepts and techniques.

Inspection Planning

Establish supplier quality relations through studies of incoming product quality, supplier rating procedures, and supplier training programmes.

Develop, instal and maintain through periodic study and analysis, plans in incoming, process and final inspection.

Conduct special studies involving complex inspection problems. Conduct studies for obtaining cost reduction by minimizing inspection effort with adequate quality protection.

Co-ordinate sound inspection practices and procedures with the E of M and Quality Assurance.

Act as a clearing house to see that good inspection practices are specified and carried out.

Process Control Surveys

Conduct surveys of shop process controls for the purpose of encouraging proper use of the process control programme, standardization of methods and elimination of obsolete procedures.

Report the results of these surveys to functional personnel and co-ordinate the resolution of some of the problems encountered.

APPENDIX F

Duties and Responsibilities of Quality Control Personnel

Manager of Quality Assurance (Bausch & Lomb Ltd. USA)

Position Objectives

The Manager of Quality Assurance, reporting to the Vice-President of Manufacturing and operations, has the responsibility for providing assurance that:

The quality of products sold by the Company will provide full customer satisfaction within the limitations determined by the product design.

The cost of quality is maintained at an economical level.

Assure that quality objectives and goals on individual products have been clearly and adequately defined for the manufacturing Divisions.

General Responsibilities

Under the Vice-President of Manufacturing and Operations, he is responsible for:

Supervision and coordination of final inspection or quality audit in all of the Rochester Manufacturing Divisions.

Investigation and analysis of customer complaints and merchandise returns.

Competitive product studies to determine market quality levels.

Maintain an adequate quality reporting system.

Provide, through inspirational leadership and example, the stimulus which results in an eager and informed cooperation on the part of his entire organization and encourages extra performance beyond individual job descriptions that results in success for the individual and thus for the Company.

Specific Duties

Policies and Objectives

a. Participate with other executives in determining the quality requirements of future products and processes.

b. Participate with other executives in the formulation of guarantee, replacement and repair policies and sales programmes in which product quality may have an important effect on Company profits or customer goodwill.

c. Assist in the determination of quality control practices and procedures which will give maximum quality assurance at minimum cost.

Organization and Personnel

a. Supervise and co-ordinate the activities of the department heads of the Final Inspection Organization.

b. Recommend the hiring, transfer, promotion and termination of his line and staff personnel.

c. Plan and execute programmes for training of inspectors, supervisors and technical personnel in the Final Inspection Organization in order to utilize people to their greatest capability.

d. Prepare measures for appraising the effectiveness of subordinates and conduct periodic reviews of progress and attainments.

Administration

a. Formulate, coordinate and implement long and short range plans for the effective and efficient operation of the quality control function in the Company.

b. Prepare direct and indirect labour budgets for the Final Inspection departments and coordinate these with the overall labour budgets prepared by the Works Manager.

(1) Administer Final Inspection departments at most economical level.

c. Review attainment of production objectives from the standpoint of eliminating unnecessary delays in final inspection.

d. Review adherence to the Company Policy Manual with respect to personnel relations, labour grades and grievances handling. Refer to the Industrial Relations for guidance and assistance where necessary.

e. Plan and coordinate the assignments made to Staff Quality Control Engineers.

Technical Functions

a. Keep up-to-date on the "State of the Art" of Quality Control.

b. Provide professional advice in the field of Quality Control when it is requested by divisions or executives of the Company.

c. Maintain a broad knowledge of the various businesses in which the Company is engaged and make decisions regarding product quality and quality costs in the light of this knowledge.

DEPARTMENT HEAD—FINAL INSPECTION (Bausch & Lomb Ltd. USA)

Position Objective

The Department Head of Quality Assurance has as his major objective the establishment of a complete system of quality control to assure that the Quality Objectives of the Company will be attained. This encompasses the areas of working with Marketing and Engineering in determining objective inspection specifications to the final shipment of the product, to provide assurance of full customer satisfaction with reasonable economic limitations.

General Responsibilities

Responsible to the Manager of Quality Assurance.

Responsible for:

a. Quality assurance of all Manufacturing Division product.

b. Investigation and answering to Sales of customer complaints.

c. Analysis of inspection, complaint and quality audit data to provide recommendations for quality improvement.

d. Assist Engineering and Sales in product evaluation.

e. Audit inspection operations delegated to the Manufacturing Division Inspection Departments.

f. Accuracy of inspection performed by his personnel.

g. Conduct studies of competitive product.

h. Provide, through inspirational leadership and example, the stimulus which results in an eager and informed cooperation on the part of his entire organization and encourages extra performance beyond individual job descriptions that results in success for the individual and thus the Company.

Authority

Has the right to inspect product during any process.

Has the right to inspect product from any process.

Has the right to request any data pertaining to the quality of work performed, process specification, product specifications or cost of inspection.

May convene meetings of line and staff personnel to discuss quality problems.

May accept or reject work. Does not have authority to stop machines or processes, but by notification to Production Control he may prevent shipment of any product judged to be non-conforming to specifications.

Has the authority to define what constitutes adequate quality assurance or acceptance.

Liaison

Supervision of Manufacturing Departments.

Supervision of Factory Engineering Departments.

Supervision of Design Engineering Departments.

Factory Accounting Department.

Payroll Department.

Industrial Relations Department.

Supervision of Engineering and Maintenance Department.

Supervision of Engineering Inspection Department.

Resident Inspectors of the Department of Defence.

Sales Departments.

Customers' representatives.

Reporting

Oral and written reports as requested by the Quality Manager.

Maintain a programme of giving essential quality reports to the management and supervision of the Manufacturing Division and to Sales and Engineering as deemed appropriate.

Specific Duties

Plan for and give general supervision to the inspection and quality control activities of his department.

Plan for and give general supervision to the training, promotion and discipline of the Inspection and Quality Control personnel of the department consistent with the practice of good management.

Assist in training Engineering and Manufacturing personnel in methods of Quality Control.

Keep up-to-date with the technology of Quality Control.

Serve as Chairman of Board of Review.

Carry out the Company Policy as outlined in the Policy Manual.

QC ENGINEERING (Western Electric Co., Allentown Works, USA)

Duties & Responsibilities of QC Engineers—Assigned to E of M Departments

Co-ordinate the introduction, maintenance and refinement of process controls on the departments functional product lines. Stimulate shop and engineering use of statistical methods for obtaining valid conclusions from data.

Conduct and analyse process capabillty studies for determining where permanent process controls should be installed, specifying the means of control, the frequency and method of checking, etc.

Prepare or approve all inspection layouts covering the process controls on functional product lines. Revise these as needed to change frequency of checks, addition or elimination of charts to maintain minimum process checking effort consistent with adequate control.

Investigate engineering and shop difficulties involving the planning, conducting and analyzing of designed experiments which may aid and expedite the elimination of the difficulties.

Determine the quality capability required of and evaluate the quality performance of new manufacturing machinery, equipment and measuring devices.

Confer periodically (weekly, by-monthly or monthly) with product engineers and shop supervisors to review and interpret charts and determine future action to find and eliminate causes of instability or out-of-control conditions.

Investigate and strive to eliminate all shop sorting operations by controlling shop processes and/or substituting sampling plans.

Work jointly with product engineers in planning, conducting and analyzing special studies and investigations of an engineering nature.

Through all of the above activities, improve or maintain the quality of the product and contribute to the reduction of merchandise losses.

Aid shop supervision on functional product lines to train process checkers in basic quality control techniques and interpretation of control charts.

QC TECHNICAL ASSISTANTS & ENGINEERING ASSOCIATES (Western Electric Company, Allentown Works, USA)

Duties & Responsibilities of Technical Assistants—Engineering Associates, Quality Control Assigned to E of M Departments

Assist engineers in the application of statistical quality control techniques to problems related to the manufacture of product.

Assist in maintaining and refining the quality control programme of inspection layouts and control charts on functional product lines.

Analyse minor production processes to determine where statistical methods would be effective.

Conduct and assist in the planning and analysis of designed experiments as developed by and under the guidance of engineers, for the purpose of controlling the effects of manufacturing variables.

Investigate shop manufacturing difficulties by comparing shop practices with manufacturing and inspection layouts and prints to detect variations from specified procedures and when no deviations are apparent, assist in making an engineering analysis of the problem.

Participate in quality meetings with operating and engineering personnel.

Prepare and issue technical reports on the results of engineering studies.

APPENDIX G

Evolutionary Operation

A Programme for Optimizing Plant Operation*

Introduction

WITH the help of Dr. George E. P. Box and Dr. J. Stuart Hunter, the Organic Chemicals Division of the American Cyanamid Company began to establish Evolutionary Operations in its manufacturing processes in June 1957. This paper is a summary of both the method as described by Dr. Box in reference (1), and our rather brief experience.

The necessity for determining the operating characteristics of a plant process need hardly be discussed here. Anyone associated with a production process is aware of the difficulty in transferring conditions established in the laboratory or pilot plant into full scale equipment.

When a process is transferred from the laboratory into full scale equipment, unquestionably the relationship between the variables remains approximately the same. For example, if it is found in the laboratory that as the temperature is increased the yield rises to a maximum and then falls, approximately the same relationship will certainly be maintained in plant equipment. However, if 78°C was optimum as determined by a thermometer inserted in a glass beaker, it does not necessarily follow that 78°C. is the optimum as measured by a thermocouple in a large steel plot. This situation is ever clearer when mechanical variables are considered. It requires no imagination at all to see the difficulty in translating the revolutions per minute of a glass stirrer to the agitator of a tank. As a result the contour system describing the relationship between the variables will usually be displaced and even distorted due to scale-up effects.

When serious difficulties are encountered in operating the plant, or when there is reason to expect that major improvements could be rapidly obtained, it may be wise to turn the plant over to experimental operation for a short time. By using a carefully chosen statistical pattern, it is possible to test many factors in a limited period of time. Of course, several major difficulties are encountered with this approach. By its very nature, the design will upset production, and usually special facilities and personnel will be needed to ensure that the complex array of experiments is properly carried through. In addition, it must be expected that some batches, as designated by the design, will produce very low yields, high levels of impurity, etc. The use of a designed experiment can certainly be justified when faced with a very sick process and the necessity of a reasonably fast cure commonly called a "crash programme". However, the vast majority of processes are just slightly ill, and faced with the prospect of an experiment disrupting production, management frequently decides that the cure is worse than the disease. For example, it is very common to find a process producing yields of 80% of theoretical while optimum laboratory conditions will produce 88%. Certainly management would like to approach, if not surpass, the 88%, but if the process is profitable at 80% and sales are heavy the motivation to approve a crash programme is weak indeed. Evolutionary Operation is designed for this type of application.

Comparison of Natural Evolution With Evolutionary Operation

Biologists declare that there are two basic elements in the process of natural evolution:

(1) Variation
(2) Selection

Since no two things are produced exactly alike in nature, there is certainly variation. By some principle, such as survival of the fittest, the undesirable members of the class under consideration are gradually reduced in favour of the desirable members. Because the variation and selection are ever continuing, the group gradually moves toward optimum characteristics.

Evolutionary Operation emulates this natural process by providing that variation and selection are artificially introduced to the manufacturing process. They are introduced in such a way that there is little danger of producing unsatisfactory material, production is not disrupted, and the normal plant personnel can continue to operate the plant on a routine basis. Evolutionary Operation is, therefore, a permanent method of plant operation not something applied on a short term basis. It works by gradually pushing the process toward its optimum operating conditions. Since the method is permanent, only techniques which can be readily understood by the manufacturing personnel are used.

General Description

Slight variation, aside from the normal process variability, is introduced by means of a carefully prescribed pattern. The pattern requires that small

*Truman L. Koehler, American Cyanamid Co., USA.

changes are made in two or three control variables about the standard operating conditions. Continued manufacture of material under the conditions described by the pattern will allow information to accumulate while material is being produced. To quote from Dr. Box's paper:

> "The effects of the deliberate changes in the variables will usually be masked by large errors customarily found on the full scale.
>
> *However, since production will continue anyway, a cycle of variants which does not significantly effect production can be run almost indefinitely, and because of constant repetition the effect of small changes can be defected."*

The second essential component selection, is supplied by presenting the data gathered to the process supervisor in an easily interpretable way so that changes toward improved manufacture can be made. Dr. Box suggests an "Information Board" which will be described in detail later in this paper. In general, accumulated data are continuously recorded on a board in the process supervisor's office in such a way that he can, at any moment, determine the advisability of moving the pattern, the cost of the programme, etc.

At American Cyanamid we have adopted the form proposed by Dr. Box with very few modifications. We have in a number of cases taken advantage of the experience of quality control eng ineers, and have posted the Information Boards in the manufacturing areas. There have been examples where yields have increased merely because interest in the operation was evidenced.

Details of the Method

To discuss the detail of Evolutionary Operation, let us consider an example. As has already been mentioned, the first important aspect of Evolutionary Operation is that changes in control variables are made according to a prescribed pattern. The following diagram shows a pattern for two controlled variables.

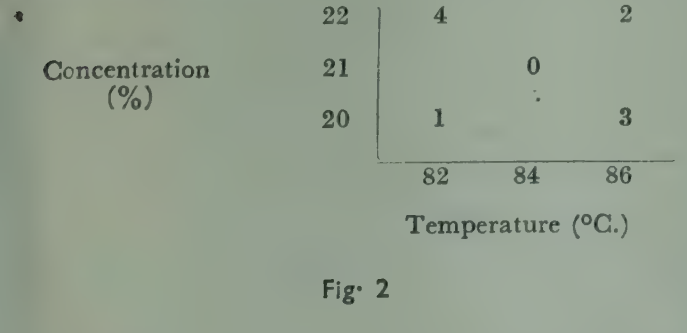

Fig. 2

Position 0 represents the standard operating conditions of temperature and concentration. Positions 1, 2, 3 and 4 represent changes in the two variables considered to be small with respect to their effect on two responses, yield and persent impurity. If this is a batch process, batches will be made successively at each of the five positions in the order 0, 1, 2, 3, 4, 0, 1, 2, 3, 4 and so on. Each set of five runs is known as a cycle. When it is convenient to do so, the order in which batches are produced is usually randomized.

The data are then tabulated on the Information Board. (Next page)

In this example, the programme is still in Phase 1, that is, the pattern is still operating about the original standard conditions. Seven cycles have been completed.

Shown at the top of the table are the responses being considered and the requirements for each. Below that appear the running averages calculated through the seventh cycle. The running averages are posted in such a way as to make the relationship between the variables as clear as possible. Since these averages are estimates of the true response under the given conditions, it is essential that a measure of their reliability be available. A measure of this reliability is provided by the "95% error limits". These limits are calculated by use of the formula $< t\, s/n$ where "n" is the number of cycles completed, "s" is the estimated standard deviation, and "t" is the appropriate quantity chosen from a table of the t distribution. A variety of probability levels are available in the table. It is clear from the formula that the programme can be continued until the quantity $t\, s/\sqrt{n}$ is reduced to any desired size. Several alternative procedures for estimating the standard deviation are given in reference (3).

Following this are the "efforts" and their 95% error limits. If the average at any point, i, is denoted by y the effects and the error limits may be calculated by the following formulas: 1

SOURCE	EFFECT	ERROR LIMITS
Temperature	$1/2(\bar{y}_2-\bar{y}_1-\bar{y}_4)$	$\angle\, ts/\sqrt{n}$
Concentration	$1/2(\bar{y}_2-\bar{y}_4-\bar{y}_1-\bar{y}_3)$	$\angle\, ts/\sqrt{n}$
Interaction	$1/2(\bar{y}_1-\bar{y}_2-\bar{y}_3-\bar{y}_4)$	$\angle\, ts/\sqrt{n}$
Change in Mean	$1/5(\bar{y}_1-\bar{y}_2-\bar{y}_3-\bar{y}_4-4\bar{y}_0)$	$\angle\, 2ts/\sqrt{5n}$

The numerical value of the temperature and concentration effects estimate the change in the response when the conditions are shifted from the center position to either the high or low level. The interaction effect measures the dependence of the two variables. Finally, the change in mean, which is merely the difference between the average of all the runs and the average at the center conditions, measures the change in the average response due to introducing Evolutionary Operation.

Phase I INFORMATION BOARD Cycle 7

Response	Yield			% Impurity		
Requirement	Maximum			Minimum		
CONC (%)	22	525	490	22	3.8	4.7
	21	530		21	4.1	
	20	540	531	20	3.8	4.4
		82 84 86 Temperature (°C.)			82 84 86 Temperature (°C.)	
95% Error Limits		$\pm$ 20			$\pm$0.58	
Effects With 95% Error Limits — Temp.	—22.0		+20	0.75		+0.58
Effects With 95% Error Limits — Conc.	—28.0		+20	0.15		+0.58
Effects With 95% Error Limits — C X T	—13.0		+20	0.15		+0.58
Change in Mean	—6.8		+18	0.06		+0.52

On the basis of the data supplied on the Information Board, the process supervisor can decide whether the process should continue to cycle around the initial pattern or whether the operation should be modified. He will make this decision, partly by considering the magnitude and direction of the effects of the variables relative to the error limits. These error limits supply a rough yardstick against which the reliability of any conclusion can be checked. For example, the limits ^{20} imply roughly that the values, 530, 490, etc., are "good" to this degree of accuracy. More previsely, we may say that all hypothesized values for the true mean response that lie inside the interval as defined by the average $\pm$ the error limits are not contradicted by the data at the 95% level of probability. Similarly, the effect,—22, associated with temperature, is in the same sense "good" to $\pm$ 20. The 95% level of probability is, of course, an arbitrary level of certainty the choice of which depends entirely on the environment.

If the process supervisor decides to modify the operation, several possible choices are:

(1) Relocate the pattern so that one of the corner points becomes the new center.

(2) Lengthen the interval over which one or both of the variables is being examined.

(3) Explore a path that is indicated as leading toward improving conditions.

(4) Replace the old variables with new ones.

A few comments should be made with regard to the relationship of the effect recorded to

the surface of the response variable. If the surface in the locale of Evolutionary Operation pattern is planar, it is completely described by the two main effects. In this case the path toward improved operation is quite clear. If, on the other hand, a large interaction or "change in mean" effect is found the assumption of planarity is not tenable. While the running averages will provide hints as to the nature of the nonplanarity, a technique described in reference (2) is used for further exploration.

Concerning the number of variables that can be conveniently run, it has been our experience at American Cynamid that two-variable programmes are probably to be preferred for inauguration purposes. However, as production personnel have become familiar with the technique, we have encouraged them to take advantage of the increased efficiency of the three-variable pattern.

Selection of Control Variables

When it has been agreed that an Evolutionary Operation programme should be initiated on a given process, a choice of control variables must be made. As the programme proceeds the effect of these variables will decrease as they approach their optimum levels. Consequently, when their possible additional contribution reaches an economic minimum, they will be dropped from the programme in favour of new variables. Consequently a continuing supply of ideas regarding possible control variables is essential. For this purpos Dr. Box recommends that "Evolutionary Operation Committees" be established.

These committees are comprised people of different disciplines with interest in the process. The nucleus of such a committee might be the manufacturing personnel, a research chemist thoroughly familiar with the reaction, and a chemical engineer who has had experience with the type of equipment used in the process. The major function of this committee is to advise the process supervisor in the operation of the programme. During meetings, held monthly perhaps, for the purpose of interpreting the results, ideas for modification of the programme will be generated.

In those areas of production in which we view the performance of Evolutionary Operation as less than ideal, there is one common deficiency—no functioning Evolutionary Operation committees. It has become quite clear that when there is no feedback of ideas to research, when little thought is given to the selection of new variables, the life blood of Evolutionary Operation is cut off. The establishment of these committees in all areas heads our list of things to be done.

An example might be given of the function of the Evolutionary Operation Committee. In a particular process in which the main reaction was carried out in a large steel tank, one of the conditions of interest was the agitation rate. The agitator, as in most large-scale units, did not have a variable speed drive, however, and a capital expenditure to instal one for investigative purposes was out of the question. Consequently the process supervisor decided that agitation could not be examined. In casual conversation with a chemical engineer of considerable experience, the suggestion was made to merely insert an air line in the tank and sparge the contents in addition to the normal agitation. This system provides the upper and lower levels of an Evolutionary Operation pattern, and even a center point if the air pressure is regulated. On the basis of this trial, it will become clear whether or not additional money should be spent to allow optimization of the agitation rate. This kind of suggestion cannot be allowed to occur by chance.

Periodically, people in addition to the nucleus already described could contribute to the meetings. An accountant, a statistician, and a person familiar with the quality aspects of the product are examples.

An Example of an Actual Programme

In setting up Evolutionary Operation on the production in the following example, two control variables were chosen.

1. Temperature (°C.)
2. Raw Material Charge (lb.)

The response measured was cost.

After four cycles, the information board appeared as follows:

Phase I — Cycle 4

Cost (lb. over $ 2.00)

Raw Material (lbs)	Temperature (°C.) 78	
34	82	78
32	77	74
	174	178

SOURCE	EFFECT	95% ERROR LIMITS
Temperature	—3.50	± 3.20
Raw Material	4.50	± 3.20
T X R. M.	—0.50	± 3.20
Change in Mean	—0.20	± 2.86

An examination of the averages and the derived effects indicate that lower cost is obtained at the

higher temperature and lower raw material usage. The 95% error limits indicate that our judgement with regard to these effects has some substance. The apparent lack of curvature in the portion of the surface on which the pattern is resting encouraged us to use the (178, 32 lb.) point as the upper lift point in the new pattern.

After seven cycles, Phase II appeared as in the following diagram.

Phase II — Cycle 7

Raw Material (lbs.)	Cost (/lb. over $2.00	
32	73	72
	71	
30	70	70
	178	182

(Temperature °C.)

Source	Effect	95% Error Limits
Temperature	−5.50	±2.20
Raw Material	−2.50	±2.20
T X R.M.	−.50	±2.20
Change in Mean	−0.20	±1.96

The effect of temperature has decreased sharply and when viewed against the error limits we fail to see any signal with respect to a favourable direction. The raw material effect and error limits on the other hand imply that still lower costs may be obtained by a reduction in the raw material usage.

Peripheral considerations tempered our judgement in relocating the pattern for Phase III. It has known that the stoichiometric amount of the raw material was about 25 lb. However, experience had indicated that an excess was necessary. Feeling, therefore, that the critical point might be quite close, the production supervisor suggested that the pattern be shifted downward just one pound.

As seen in the next diagram, this decision was a wise one.

Phase III — Cycle 5

Raw Material (lbs.)	Cost (/lb. over $2.00	
31	7	72
	70	
29	74	75
	178	182

Temperature (°C.)

Source	Effect	95% Error Limits
Temperature	−0	±2.92
Raw Material	−2.00	±2.92
T X R. M.	−1.00	±2.92
Change in Mean	−2.80	±2.61

The shape of the surface in the local of the pattern appears to have changed rather drastically from that in Phases I and II. The change in mean effect has become quite prominent. Actually it is important to point out that the five-point pattern is incapable of completely describing the nature of the curvature, and we have in a number of case segmented the pattern to gain increased information. On this process, however, a long list of variables was waiting to be tried, and it was decided to set temperature and raw material at 180 C. and 30 pounds, respectively, and proceed with two other variables.

Conclusion

Our experience with Evolutionary Operation has been most gratifying. Unfortunately our program is still too immature to report the over-all economic gain. There is little doubt that it will be considerable. Perhaps it is equally important to point out that the concept of Evolutionary Operation is generally being instilled as a normal method of production. We feel quite confident that Evolutionary Operation will be increasingly expanded in our manufacturing area.

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APPENDIX H

Development of Quality Control in some Factories

A brief history of Quality Control in Toyo Rayon Co., Japan.

1949 Some methods of Statistical Quality Control were digested and introduced into the company by the Research Laboratory staff.

1950
(1) Chairman of the Board of Directors and President took lectures at Dr. Deming's Quality Control seminar in Japan and attaching importance to Quality Control, Chairman commanded all the company to adopt Quality Control system.
(2) Quality Control studies were promoted centering around the Research Laboratory.
(3) Dr. Mizuno and others visited the Company and gave instructions.
(4) "Control Chart Method" was introduced.

1951
(1) Quality Control Committee was organised within each plant.
(2) Dr. Deming visited the company.
(3) Lecture courses inside the company were held with outside lecturers, Dr. Ishikawa, Dr. Mizuno, Dr. Asaka, Dr. Masuyama and others.
(4) Some staff members attended the Quality Control Basic Seminar sponsored by JUSE. (The number of completing ing the seminar amounts to 156).
(5) Methods of "Designed Experiment" and "Sampling Inspection" were introduced and put in practice.

1952
(1) The center of Quality Control study was removed from the Research Laboratory to the Technical Department.
(2) Operation Standards began to be established.
(3) "The Main Principle of Education" was established.

1953 Quality Standards began to be established.

1954
(1) Quality Control Committee for the entire Company was organized.
(2) Quality Control Section was set up within each plant.
(3) "The Deming Prize for Quality Control Practicing" was awarded to the Company.
(4) Dr. Juran visited the company.
(5) Study of OR was begun.

1955
(1) Some staff members attended the OR Seminar sponsored by JUSE. (The number of completing the seminar amounts to 33).
(2) Some middle managers attended the Quality Control Management Seminar sponsored by JUSE. (The number of completing the seminar amounts to 94).
(3) Dr. Deming visited the company again.
(4) Quality Control Campaign was begun.

1956 Quality Control Assurance was begun.

1957
(1) The 1st Annual Conference of Quality Control within the company was held.
(2) Industrial Engineering (IE) was formally introduced into the company.
(3) Productive Maintenance (PM) was formally introduced into the company.
(4) Quality Control Section was set up as an over-all company staff at the Osaka Headquarters.
(5) Quality Control orientation and guidance to our related Company were begun.

1958
(1) Quality Control Section and IE Section were set up in the Production Administrative Department.
(2) Quality Section in each plant was reduced to Control Section including Quality Control and IE function.
(3) "The Statistical Methods by Step System" was published as a standardized textbook.
(4) Suggestion System was established.
(5) Chart Room for discussing and study of Quality Control problems was set up in each plant.

1959
(1) Dr. Pabst visited the company.
(2) IE education inside the company was pushed forward.
(3) OR Research Committee was set up in the company.

1960
(1) Quality Control Game was perfected.
(2) "Mandel Project" was planned.

(3) "The Quality Control Literature Prize" was awarded to the statistical Methods by Step System.

(4) Quality Control Section and IE section were reformed to Control Section.

(5) Dr. Deming visited the company again.

1961 (1) Inner rules of Quality Control, Operation Standards, Product & Material Standards, etc., were re-established.

(2) Study of EDP was begun.

Brief Outline of the Evolution of Statistical Quality Control at Western Electric Company, USA.

1950

October Started sending Statistical Quality Control engineers to two-week basic course at various universities. Fourteen engineers sent through 1955.

1951

June Began attendance at and active participation in ASQC sectional, regional and national meetings representing Western Electric Company.

June-July $\bar{X}$ R charts on E.T. final test characteristics plotted by statistical clerk (204 grade) in central plant area.

August Four Statistical Quality Control engineers in Inspection Organization.

Charts displayed at operation or machine.

Started standardization of process controls, chart forms, chart holders, and data sheets.

September Started transfer of sorting from Inspection to Operating.

October Inspection Layouts written to formalize process checking procedures.

December Statistical clerks hired for chart work. (January 1956: 5 statistical clerks, grade 204).

1952

Jan-April Basic 18-hour programme for all engineers and supervisors.

January De-emphasize concept of "inspecting" quality into product at inspection and emphasize quality in make operations.

March Assignment of specific areas in plant to each Statistical Quality Control engineer.

March-April Evaluation and review of use of charts began

April-May Examples of applications of charts and resultant savings formulated to justify 5220 existence.

June Started transferring process checkers from Inspection to Operating. Completed during 1953.

Charts submitted to BTL as a basis for specification revisions.

Started to explore proper treatment of process control effort for wage incentives.

Advent of quality team and quality meeting approach to solution of manufacturing problems. Review of charts, delegation of action, and issuing of minutes of Statistical Quality Control meetings.

November Combined four Statistical Quality Control engineers and six shrinkage control engineers into one Statistical Control department.

December Statistical Quality Control emphasized at engineers'-supervisors' dinner.

1953

February Statistical Quality Control approach to operator responsibility for junk.

March MDI issued outlining procedure for writing and issuing Inspection and Process Control Layouts.

Held three-hour follow-up refresher course for engineers and supervisors stressing purpose of full-job coverage.

Advent of meetings with operators to explain purpose and use of charts. Coordinated by supervisor, product engineer, and Statistical Quality Control engineer.

April Started Statistical Quality Control articles in "Electronicle" for six successive issues.

June Basic six-hour "Introduction to Design of Experiment" course for Statistical Quality Control engineers and product engineers.

Application of Statistical Quality Control to non-manufacturing problems, such as absenteeism, maintenance.

September — Statistical Quality Control authorized as basis for cost reduction cases.

Initial effort begun to comply with Signal Corps R.I.Q.A.P. Entire plant qualified in June 1955.

1954

January — Start of frequent visits to Allentown Plant to observe the Statistical Quality Control programme by other locations, college students, other companies and foreign delegations.

March — Allowance for process control effort provided for in 1955 Bulletin planning.

May — Basic six-hour training course for all layout operators and process checkers.

June — Initial effort started to compile Statistical Quality Control Handbook for Allentown. In February 1955, E. of M. staff conference authorized preparation of Manufacturing Division Statistical Quality Control Handbook.

Started sending Statistical Quality Control engineers to 10-day advance Statistical Quality Control course at Purdue. Two engineers sent through 1955.

1954

June — Statistical Quality Control engineers present skit "Sampling Inspection" to Manufacturing staff conference held at Allentown.

August — Started to compile for permanent record copies of Statistical Quality Control material for distribution locally and to other locations.

September — First product line (Switch board Lamps) utilizing authorized shrinkage payments based on control charts.

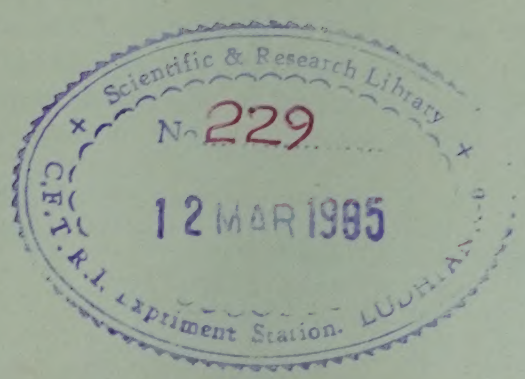
December — Initial publication of monthly Merchandise Loss per Dollar Stocked Report by product lines to reflect actual reduction in junk and repair effort from 1951 on.

1955

June — Gradual transfer of Statistical Quality Control engineers to shop supervision and to E. of M.

July — Allentown Plan products authorized for R.I.Q.A.P. by the Signal Corps.

Expansion of Statistical Quality Control department started. New engineers hired and technical investigators added. (January 1956: 11 engineers and 2 technical investigators.)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